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THE UNIVERSITY OF ALBERTA

EFFECT OF WINTER FEEDING PROGRAMS ON
WEIGHT CHANGES, CALVING, AND LACTATION
OF WAPITI (CERVUS ELAPHUS NELSONI) ON GAME FARMS

by

(C) Henry Michael Kozak

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

IN

WILDLIFE PRODUCTIVITY AND MANAGEMENT

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

FALL 1988

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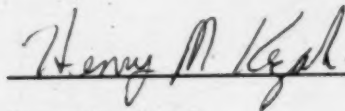
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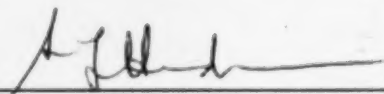
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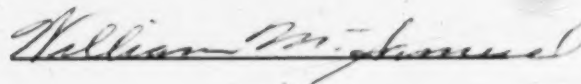
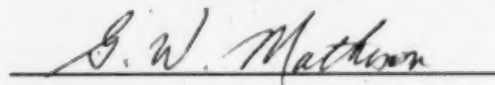
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled EFFECT OF WINTER FEEDING PROGRAMS ON WEIGHT CHANGES, CALVING, AND LACTATION OF WAPITI (CERVUS ELAPHUS NELSONI) ON GAME FARMS submitted by HENRY M. KOZAK in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in WILDLIFE PRODUCTIVITY AND MANAGEMENT.



Supervisor



Date: August 8 1988

This thesis is dedicated to my parents,
Hank and Martina Kozak,
who I am indebted to for their understanding,
unfailing support and encouragement.

Abstract

Some of the commercial aspects of managing wapiti on game farms in Alberta were investigated in 1984-86. Emphasis was placed on winter feeding programs, specifically effects of winter nutrition on weight change and subsequent reproductive performance, lactation, and calf growth. The biological and economical implications of different forms of supplements were investigated. Supplemental winter feeding was the main treatment in the study; groups of wapiti hinds were either pastured (without supplement), supplemented with a long-hay, or supplemented with an alfalfa/barley pellet through the winter.

The provision of pelleted feeds to wapiti hinds resulted in higher levels of foraging behavior than the provision of long-hay. Consumption of concentrate by pellet-supplemented hinds was higher than the consumption of hay by hay-supplemented hinds while there was no significant difference in weight gains between the groups. There was no advantage in feeding processed feeds to pregnant hinds during winter.

Unsupplemented wapiti hinds lost significantly more weight than supplemented hinds, which maintained or gained weight. Weight losses, until May 1, of up to 10% of autumn weight did not adversely affect calving. Supplementation did not affect subsequent weight or vitality of calves at birth. Dystocia occurred most frequently in supplemented hinds suggesting that overfeeding of wapiti hinds may cause dystocia. Calves from hinds experiencing dystocia were significantly less vital at birth than those with normal births.

Conception rates in adult hinds exceeded 90%, although hinds needed to reach a mean target weight of 228 kg in order to become pregnant as yearlings. Weight of calves at birth was significantly correlated to age and autumn weight of the hind.

Milk volumes were significantly higher in supplemented hinds than in hinds which were not supplemented the previous winter, and peak milk volumes occurred earlier in lactation. Although milk from unsupplemented hinds contained slightly higher levels of protein, fat and lactose, there was no significant difference in milk energy content (kJ/g) between supplemented and unsupplemented hinds. Hinds which had been supplemented the previous winter provided significantly more milk energy per day to their calves due to the significantly higher volumes produced by supplemented hinds. Milk from unsupplemented hinds had significantly higher proportions of C18:1 fatty acids. No differences were found between daily activity patterns of calves from supplemented or unsupplemented hinds. Lactation failure occurred only in hinds supplemented with pellets suggesting that barley-based supplements may induce lactation failure.

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I. GENERAL INTRODUCTION

A. History of Game Farming/Ranching

The concept of game ranching is by no means recent; evidence from archeological sites in Europe suggests that red deer (Cervus elaphus elaphus) were husbanded in an incipient manner as long as 50,000 years ago (Jarman 1972). For many centuries, various species of deer have been kept in Eastern countries, often under domestic conditions, to provide antlers and other by-products that remain in demand for their supposedly tonic properties (Yerex 1982). Deer farming has a long history in China where at least 200,000 deer are farmed (Pinney 1981). In China, the industry is largely based on the production of antler velvet for medicinal purposes, but these animals undoubtedly also contribute to the country's meat supply (Haigh 1982).

Intensive management of deer for production of meat is a modern development (Kay et al. 1984). In New Zealand, the commercial venison industry began in the late 1950's with the development of export markets, primarily in West Germany (Drew 1976). High prices paid for venison stimulated rapid growth of the industry and intensified shooting pressure. As numbers of feral deer dwindled, farmers began to capture feral animals and place them in enclosures. Game ranching legislation was passed in New Zealand in 1969 and the industry developed rapidly. The number of deer farms, now numbering over 2000, is increasing rapidly as more conventional livestock farmers see deer as viable diversification (Wilson 1984). From

approximately 30 to 40,000 farmed deer (primarily red and fallow deer (Dama dama)) in 1978 to 98,000 in 1980, the population is now above 300,000 and estimates are for over 3/4 million farmed deer by 1990 (Wilson 1984). Venison comprises the bulk of New Zealand exports; 2000 to 3000 tonnes valued at CDN \$16 to 25 million are exported annually. Velvet antlers are the second major product providing an additional CDN \$10 million annually.

In Scotland, the hill sheep industry was considered to be ailing and it was thought that red deer might prove superior (Kay et al. 1984). The British Deer Farmers' Association was founded in 1978 and there are over 4000 breeding hinds held on farms in the United Kingdom (Kay et al. 1984). At Glenslaugh, Scotland, an experimental deer farm was established in 1970. Development of the industry has been limited by availability of breeding stock.

B. Production Systems For Western Canada

The potential to ranch bison (Bison bison), wapiti and moose (Alces alces) separately or in a mixed grazing system on marginal lands has been investigated in recent years and the agricultural potential of wildlife has been firmly established (Telfer and Scotter 1975, Hudson and Bunnell 1980, Gates and Hudson 1981a,b, Hudson 1981, 1984).

Only a handful of game farms were present in Canada a decade ago, with only six raising deer species. Approximately 4,900 wapiti, 3,200 fallow deer and 350 red deer are held on 222 game farms located across Canada in British Columbia, Alberta, Saskatchewan, Manitoba, Quebec, Ontario, N.W.T., Yukon and the Maritime Provinces (Renecker 1987). Alberta with its vast expanses of aspen parkland/boreal mixed-wood vegetation is particularly well suited to the raising of large ungulates in captivity. Registered game farms in Alberta have increased in number from 15 in 1986, to 84 in 1987, with approximately 2,700 head of wapiti held on 4,900 ha (Renecker 1987). Revisions to the Alberta Wildlife Act (Autumn, 1984 Session of the Legislature) have laid the legal basis for wapiti farming to become a significant agricultural industry in the province, although the future still depends on legalization of venison sales.

In western Canada, game production was originally seen as an 'appropriate technology' for marginal lands. The strategy of ranching mixed species was based on an economy of scale in which perimeter fencing costs were diluted by enclosing vast areas. However, absolute investments are high and few investors have access to the large contiguous land bases that are required. These economic facts of life, plus regulations pertaining to the production and slaughtering of game, limit opportunities for extensive game ranching to native people with a communal land base. Therefore, the major contribution to production will come from small intensively-managed game farms (Renecker and Kozak 1987).

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Efficient farm production begins with the development of an appropriate annual management cycle. This cycle includes movement of animals to different grazing areas and to handling facilities for inspection, veterinary treatment, removal of velvet antlers and, eventually, slaughter. In the autumn, animals must be gathered to wean calves and separate stock into breeding or special winter-feeding groups. Such manipulations can only be accomplished with firmly habituated animals and a management system that is safe for both man and animal.

C. Current Research

Research support for the fledgling game industry comes from a continuing series of studies at the Ministik Field Station. The earliest studies outlined the general ecological and bioenergetic characteristics of wapiti. Westra and Hudson (1979) evaluated the digestive characteristics and nitrogen metabolism of wapiti. Gates (1980) investigated the behavior and productivity of wapiti in relation to the strongly seasonal boreal mixed-wood environment. Pauls et al. (1981) evaluated seasonal energy expenditures of wapiti. Nietfeld (1983) investigated foraging behavior of wapiti in five habitat types. More recently, Watkins (unpubl.) investigated bioenergetic adaptations of wapiti to seasonal environments. He examined the influence of nutrition on seasonal changes in metabolism, activity budgets, habitat selection, and blood chemistry.

D. Scope and Objectives

These studies provided a clear picture of the adaptability of wapiti. However, it was necessary to design appropriate commercial management systems. Thus, the aim of this study was to 1) design husbandry systems, specifically those related to winter feeding for wapiti and 2) to develop appropriate standards of animal care.

Emphasis was placed upon programs of winter feeding. The specific objectives were to investigate:

1. the biological and economic implications and practicality of supplementing the winter diet of hinds with feeds of different physical form;
2. the effect of winter nutrition on reproductive performance of wapiti hinds; and
3. the effect of winter nutrition on milk production of hinds and growth of their calves.

II. STUDY AREA, ANIMALS, FACILITIES AND TREATMENTS

The study was conducted at the Ministik Wildlife Research Station (SEC 26 TP 50 R 21 W 4) located approximately 50 km SE of Edmonton, Alberta (Fig. II.1): The station is situated in the Cooking Lake moraine within the southern fringe of the aspen dominated boreal forest zone (Rowe 1972). The station is comprised of approximately 265 ha surrounded by a 2-m high game fence. The station is divided into a game ranch portion containing 194 ha and a game farm portion containing 65 ha.

A. Geology and Soils

The Ministik area is underlain by the Edmonton Formation, an Upper Cretaceous bedrock of shales, sandstones, clays and coal interbedding (Bayrock and Hughes 1962). The Cooking Lake Moraine overlies the Edmonton Formation and is composed of glacial debris formed during the retreat of the Wisconsin ice sheet. The area is characterized by gently rolling to rolling hills and shallow depressions, typical of hummocky dead-ice moraine. There are numerous seasonal and permanent shallow water bodies (sloughs) located in the area.

Luvistic soils, derived from calcareous, fine-grained till (Bowser et al. 1962, Crown 1977) are predominant in the Ministik Lake area. The forest soils of the area are classed as fairly

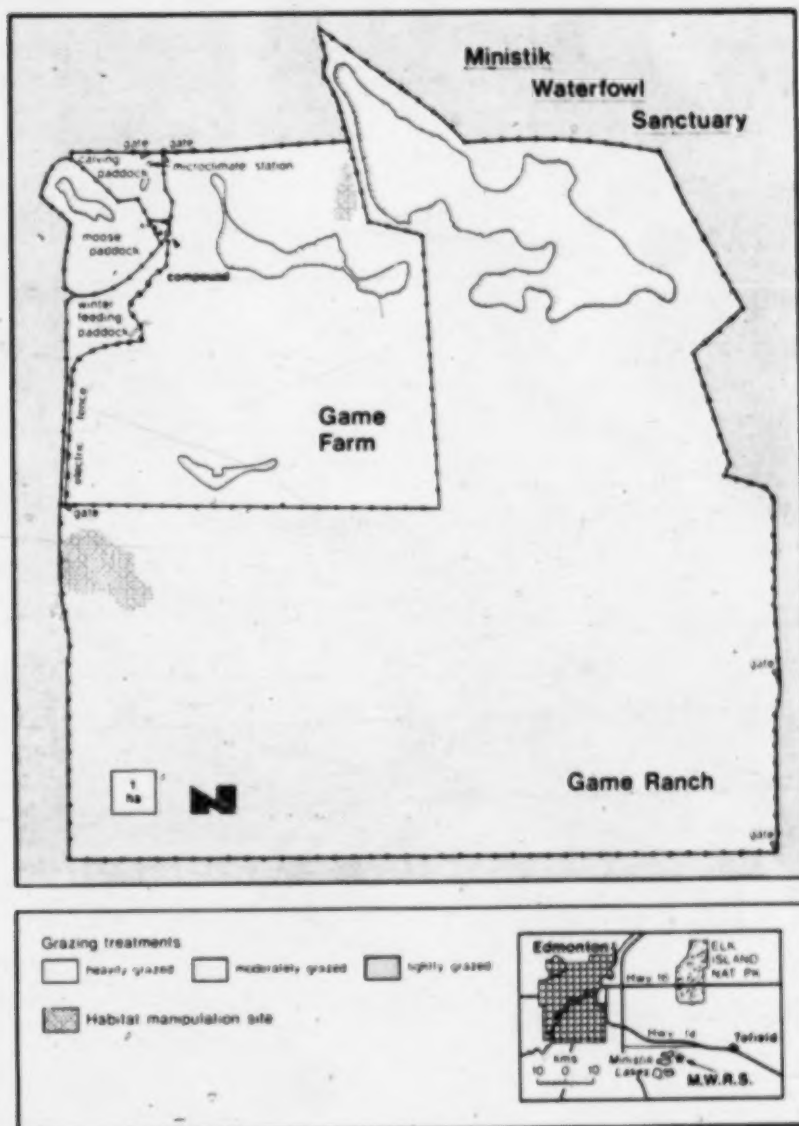


Figure II.1. Layout and geographical location of the Ministik Wildlife Research Station (M.W.R.S.), in central Alberta.

well-drained Orthic Grey Luvisols, whereas the poorly drained mineral soils are classed as Humic Luvic Gleysols. Organic soils are common in depressions.

B. Climate

The Climate of the Ministik Lake area is cool, and continental with short warm summers and long cold winters (Wonders 1969). The frost-free period averages 100 days and the average wind velocity is less than 26 kph. Summer temperatures are generally warm with a mean June to September temperature of 15 °C (Olson 1985). The winters of this area are typically cold and dry with ambient temperatures in January ranging from -49 °C to 10 °C. Annual precipitation averages 500 mm, with 25% as snowfall (Anon. 1980). Generally, accumulations of snow occur in late November and persist until April.

C. Vegetation

The aspen-dominated boreal forest zone is composed of a mixture of forest and grassland in a mosaic pattern with numerous aquatic communities (Bird 1966). The study site was homesteaded early in the twentieth century, which created a greater interspersation of habitat than found on undisturbed sites (Nietfeld 1983). The scarcity of

conifers and mixture of open grasslands and forest gives the area some of the characteristics of the aspen parkland. Gates (1980) classified the vegetation cover of the Ministik Field Station into five habitat types: poplar forest, willow, sedge meadows, upland grassland, and lowland grassland.

Poplar forest was the dominant cover type, occupying 47% of the area (Gates 1980). Trembling aspen (Populus tremuloides) dominated drier sites, while balsam poplar (P. balsamifera) dominated the more mesic sites. The most common shrubs in the understory of the poplar forest were beaked hazelnut (Corylus cornuta), rose (Rosa acicularis and R. woodsii), raspberry (Rubus melanolasius), and saskatoon (Amelanchier alnifolia). Numerous seasonally abundant forbs were present as well as brome grass (Bromus pumpellianus) and bluegrass (Poa spp.). A fire in this area in the 1890's resulted in white spruce (Picea glauca), the dominant climax species of this forest zone, being poorly represented on the study area (Gates 1980).

The willow habitat occupied about 12% of the study area (Gates 1980), forming a band around the sedge meadows. Willow (Salix spp.) was the dominant cover species, although balsam poplar was present in some areas. Sedges (primarily Carex atherodes) and reedgrass (Calamagrostis canadensis) were the main understory species.

Sedge meadows occurred on 11.5% of the area (Gates 1980), with Carex atherodes as the principal species. Cattails (Typha latifolia) occurred along the open water edge of the sedge meadows, and reedgrasses and forbs occurred near the shore edge of the meadows.

Upland grasslands occupied 19.1 % of the study area (Gates 1980),

and occurred in cleared upland forest areas. The areas were seeded in the early 1900's, and native species have not yet replaced those introduced. Bluegrass and brome were the dominant grass species. Forbs included clover (Trifolium spp.), dandelion (Taraxacum officinale), and strawberry (Fragaria virginiana var. glauca). Shrubs; snowberry (Symphoricarpos spp.) and rose, were frequent on only a few sites. Poplar regeneration was infrequent on the upland areas.

Lowland grasslands occupied 4.4% of the area (Gates 1980). The major lowland grassland site had also been seeded. Bluegrass, brome, wheatgrass (Agropyron cristatum), and reedgrass were the dominant species present. Canada thistle (Cirsium arvense) was the predominant forb.

D. History

The Ministik Field Station was established by the Alberta Wildlife Production Research Committee in 1976 and, at that time, 65 ha of the reserve was fenced. An additional 200 ha of fencing was completed in 1982 and the property was officially leased to the University of Alberta in 1985.

The foundation stock of nine wapiti (Cervus elaphus nelsoni), which were hand reared, was introduced from the Sybille Wildlife Research Station at Sybille, Wyoming in 1976. Five calves, originating from western Alberta, were introduced in 1977 from foundation stock at the University of Alberta. In 1980, three calves

from Elk Island National Park were introduced. Recent introductions of breeding bulls obtained from Elk Island and the Alberta Wildlife Park have been made in order to maintain genetic diversity of the herd. The remainder of the wapiti maintained at Ministik have been born and raised on site.

E. Winter Feeding Treatments

This study was conducted over a two-year period utilizing winter feeding as the main experimental treatment. Winter feeding groups were formed as in Table II.1. During the winter of 1984-85, four wapiti hinds (unsupplemented group) were run on native range without supplementation in order to induce about 10% body weight loss from peak fall weights to the time of parturition as probably occurs in wild populations. Eight others (pellet group) were offered alfalfa/barley pellets ad libitum (Tables II.2, II.3). The age of animals in the pasture and pellet groups were balanced but contained an unbalanced number of animals in each group because they also were part of an unrelated study. The groups were used opportunistically for the first year of this study. Initiation of these treatments was on November 1 (at the time of significant snowfall) with the intent of continuing until the green-up period in May. However, the harsh winter required intervention by February 1, 1985 when the unsupplemented group were supplemented at maintenance levels, with long-hay until calving.

The following winter (1985-86), three treatment groups were

Table II.1. Allocation of wapiti hinds to winter feeding groups at M.W.R.S. during the winters of 1984-85 and 1985-86^a.

Unsupplemented Group		Pellet Group		Hay Group	
Winter 1984-85:					
Blue	7746 ^b	Elke	7650		
Black	7749	Bell	7747		
Jasmine	8235	Beauty	8229		
Ebony	8304	Honesty	8055		
		Teen	8113		
		Crystal	8310		
		Ariel	8059		
		Wildgirl	8044		
Winter 1985-86:					
Cinnamon	8414	Crystal	8310	Rosemary	8417
Ginger	8415	Pekoe	8420	Pepper	8418
Nutmeg	8416	Sugar	8421	Honesty	8055 ^c
Ebony	8304	Beauty	8229 ^c	Ariel	8059 ^c
Blue	7746 ^c	Teen	8113 ^c	Black	7749
Jasmine	8235 ^c	Wildgirl	8044	Bell	7747
Elke	7650	Patti	8058		

^a The first two numbers of the tag number represent year of birth.

^b Name and number of each wapiti.

^c Accompanied by calf through winter.

Table II.2. Formulation of the pelleted supplement used to supplement wapiti hinds at M.W.R.S.

Ingredient	Percent of Composition
Dehydrated Alfalfa	25.58
Barley	31.09
Wheat Shorts	14.04
Beet Pulp	16.05
Soybean Meal	8.53
Molasses	4.01
Trace Min. Salt	0.40
Vitamin A D E	0.20
Permapellet	0.10

Table II.3. Chemical composition of feeds (dry matter basis) used to supplement wapiti hinds at M.W.R.S.

Item	Pellet	N ^a	Hay	N ^a
Dry Matter (%)	87.10 ^b (0.09) ^c	3	85.00 (0.05)	3
Protein (%)	16.60 ^b (0.16)	3	8.81 (0.16)	3
Gross Energy (kJ/g)	17.95 (0.02)	2	17.62 (0.01)	2
Digestible Energy (kJ/g) ^d	15.36 ^b (0.02)	2	13.17 (0.61)	2
Neutral Detergent Fiber (%)	32.39 ^b (0.22)	3	57.48 (0.37)	3
Acid Detergent Fiber (%)	16.37 ^b (0.20)	3	32.39 (0.21)	3
Lignin (%)	2.85 ^b (0.13)	3	4.47 (0.06)	3

^a Number of samples.

^b Significant difference ($P > 0.05$) between means.

^c Numbers in parentheses are standard errors of the mean.

^d Estimated using in situ technique.

formed. The age of the hinds in the groups were balanced and the number of hinds in each group was randomly assigned. The calves were not weaned (due to lack of facilities) therefore, two hinds with calves were assigned to each group. The "unsupplemented group" (seven hinds and two calves) was allowed to forage on natural vegetation without supplementation. A "pellet group" (seven hinds and two calves) was offered alfalfa/barley pellets ad libitum, and a "hay group" (six hinds and two calves) was offered unlimited access to long-hay (grass/alfalfa) (Table II.3). The treatments were initiated December 1, 1985 (at the time of significant snowfall) and terminated May 1, 1986 at the beginning of the spring green-up period.

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III. INFLUENCE OF SUPPLEMENTAL WINTER FEEDING ON INTAKES, WEIGHT CHANGES AND FORAGING BEHAVIOR OF FARMED WAPITI

A. Introduction

Due to logistic and economic constraints, farmed wapiti tend to be managed rather intensively (Renecker and Kozak 1987). Intensive management involves high stocking rates on relatively small acreages and, thus, the need arises to provide supplemental feed, especially during winter.

Supplemental feeding is practiced for three reasons: to habituate and control stock; increase carrying capacity; and complement pasture forage. Generally, taming is facilitated by the reinforcement of controlled daily feeding. The two other objectives are served by changing the physical form or the chemical composition of the feed. Concentrate may be offered where pasture is available but of low quality whereas hay may prove more practical when animals are simply maintained through lean periods.

Wapiti are extremely adaptable in their dietary preference (Gates and Hudson 1981). Economy and local availability are two factors that must be considered, but the physical form of the feed can have management implications as well. This study was conducted to evaluate the effect of physical form of supplemental feed on the

performance, natural foraging behavior, and economics of wapiti in the winters of 1984-85 and 1985-86.

B. Methods and Materials

Weight Records

Wapiti were weighed biweekly with an electronic platform scale (Western model no. DF-1000 Accurate Scale Industries, Edmonton, Alberta). Supplemental feed was withheld for a period of 2 - 4 days prior to weighing in order to entice the animals into corrals. Natural forage and water were not restricted prior to weighing therefore, body weights included rumen fill.

Feed Consumption

Daily feed consumption (kg/hd) was calculated from average monthly feed consumption and the number of animals in each group (corrected for the days feed was withheld). Data was collected from November to April in 1984-85, and from December to April in 1985-86. Monthly feed records were compiled from gross kg of feed put into feed troughs in order to simulate farm conditions. The amount fed (kg/month) was divided by the number of animals in each group (including two calves per group in 1985-86). Random samples from each feedstuff were analysed for gross energy, protein, neutral detergent

fiber, acid detergent fiber and lignin (Goering and Van Soest 1970), with neutral detergent fiber in the pellets being determined after amylase pre-treatment (McQueen and Nicholson 1979). Dry matter digestible energy was estimated at The Alberta Environment Centre using the in situ technique (Hawley et al. 1981, Neathery 1969). Chemical analysis of the feeds is presented in Table II.3.

Foraging Behavior

In 1986 additional information on foraging behavior was collected. A dawn-to-dusk (10 hour) behavior scan was conducted in January, February and March, (1986). Seven hinds and two calves were observed in the group supplemented with pellets and six hinds and two calves were observed in the group supplemented with hay. All animals were fitted with identification collars to facilitate observations. The two groups were observed simultaneously using one observer per group for the entire sampling period. All observations were made at distances of 10 - 50 m with the aid of binoculars. Instantaneous scan sampling at 10 minute intervals (Jacobson and Wiggins 1982) was used to determine the time spent in the following four activities:

- 1) Feeding included consumption of supplemental feed only; 2) Browsing/grazing included the consumption of natural vegetation only;
- 3) Active (Non-Feeding) included any energy expending activity excluding feeding or browsing/grazing such as walking, running or play; and 4) Inactive included any behavior, such as lying or lying ruminating, that required little or no energy expenditure. Bouts of behavior were said to end when a different type of behavior began (Lehner 1979).

Statistical Analysis

Data were analyzed using methods of Steel and Torrie (1980) and the SPSS-X User's Guide (Anon. 1983). Winter weights of the hinds were analyzed using analysis of variance and Student-t tests were used to determine differences between the mean number of observations in each behavioral category and to detect differences in the chemical composition of feedstuffs. A 95% ($P < 0.05$) level of significance was chosen to separate significant results from non-significant results.

C. Results

Supplemental Feed Intake and Weight Change

The monthly pattern of feed intake in winter, 1985-1986 was similar between the two groups but the daily intake of hay was approximately 1 kg/hd/d lower than that of the pellets in all months (Fig. III.1). The pattern of pellet intake in 1985 was similar to 1986 but slightly lower in all months (Fig. III.1).

During 1984-1985, there was a significant difference ($P < 0.001$) in the monthly weights between the pasture and pellet group and in the treatment by month interaction ($P < 0.05$) (Fig. III.2). The unsupplemented group underwent rapid weight loss until February at which time they had lost 11% of November weight. At this time, the unsupplemented group was brought in from pasture and supplemented at maintenance with grass/alfalfa hay until calving. The pellet group gained weight throughout the winter and finished in April with a gain of 4% of their November weight.

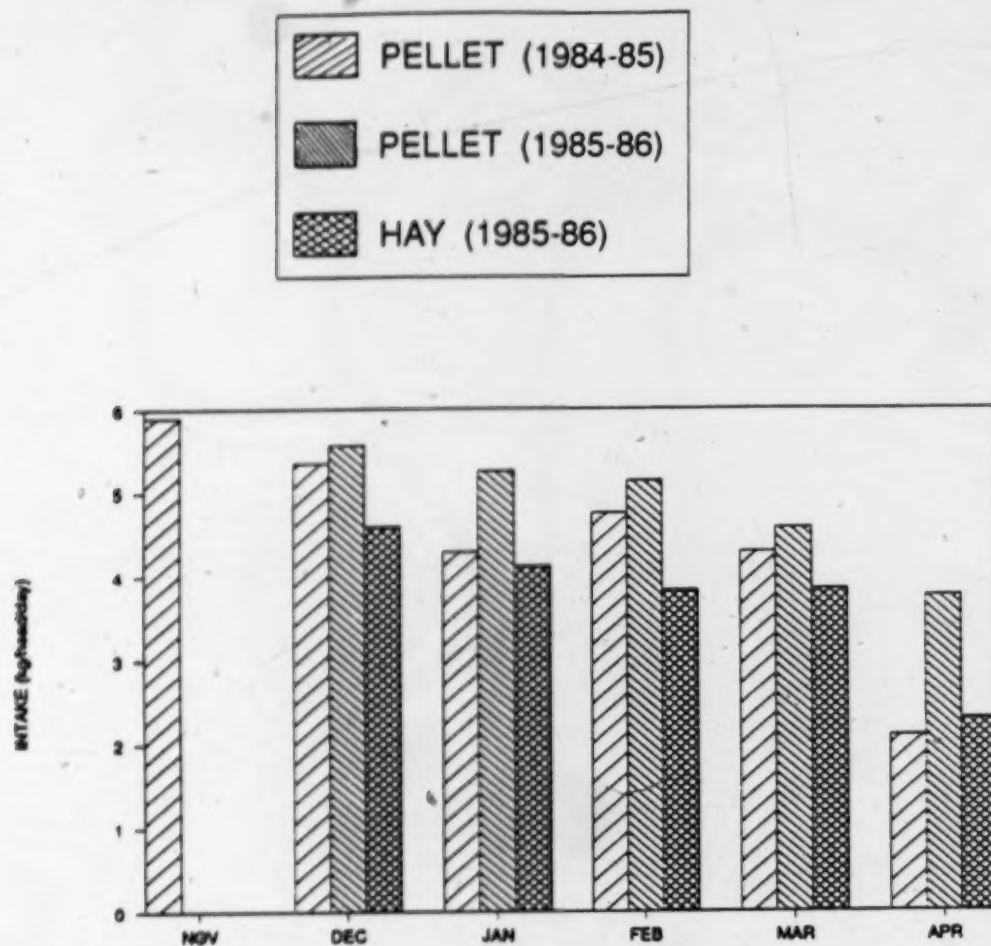


Figure III.1. Estimated daily intake (kg/head) of supplemental feed by wapiti hinds on two different rations, winters 1984-85 and 1985-86 at M.W.R.S.

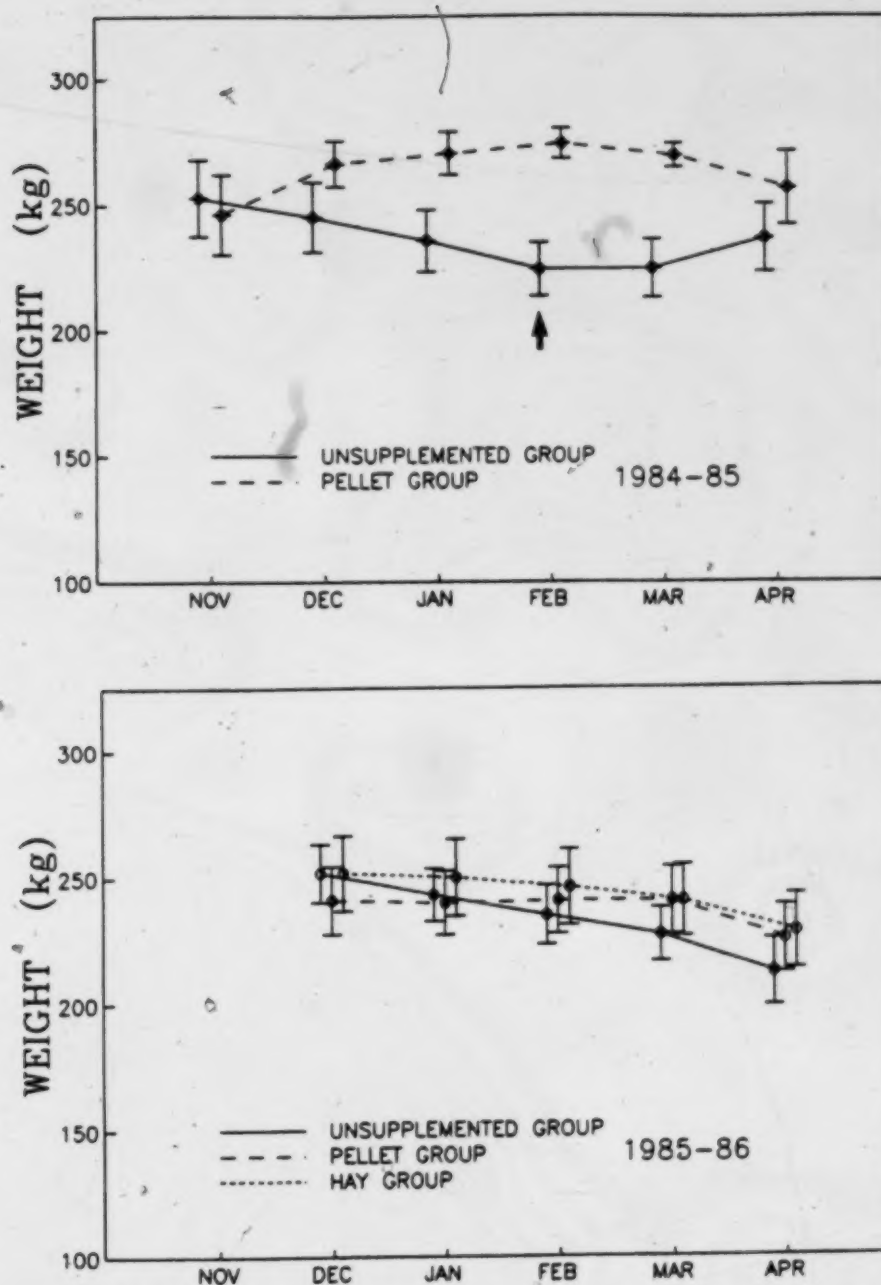


Figure III.2. Mean $\pm$ SE monthly winter weights of unsupplemented, hay-, and pellet-supplemented wapiti hinds, winters 1984-85 and 1985-86 at M.W.R.S. ($\blacktriangle$) Unsupplemented group taken off pasture and supplemented with grass/alfalfa hay.

During 1985-1986, there was no difference ($P > 0.05$) in the absolute weights between the pellet and hay groups, but there was a significant ($P < 0.001$) treatment by month interaction (Fig. III.2). The pattern of weight change between unsupplemented group and two supplemented groups differed significantly ($P < 0.05$) while there was no significant difference ($P > 0.05$) between hay and pellet groups. The unsupplemented group underwent weight loss (16% of December weight), from December to April, followed by the hay group (9% of December weight) and the pellet group (6% of December weight). Weights increased until March in the pellet group with weight loss occurring between March and April.

Activity Budgets

A significant difference ($P < 0.001$) was found in foraging patterns between wapiti receiving the pellet supplement and those offered hay (Fig. III.3). In each month, animals fed hay showed a complete absence of browsing or grazing, but instead allocated their entire feeding time towards the consumption of supplement. In January, there was no significant difference ($P > 0.05$) between levels of active (non-feeding) or inactive behavior between the two groups. In February, there was a significant difference ($P < 0.001$) in the inactive behavior between the two groups with the hay-supplemented group showing higher levels of inactivity but there was no significant difference ($P > 0.05$) in the level of active (non-feeding) behavior. In March, differences had essentially disappeared.

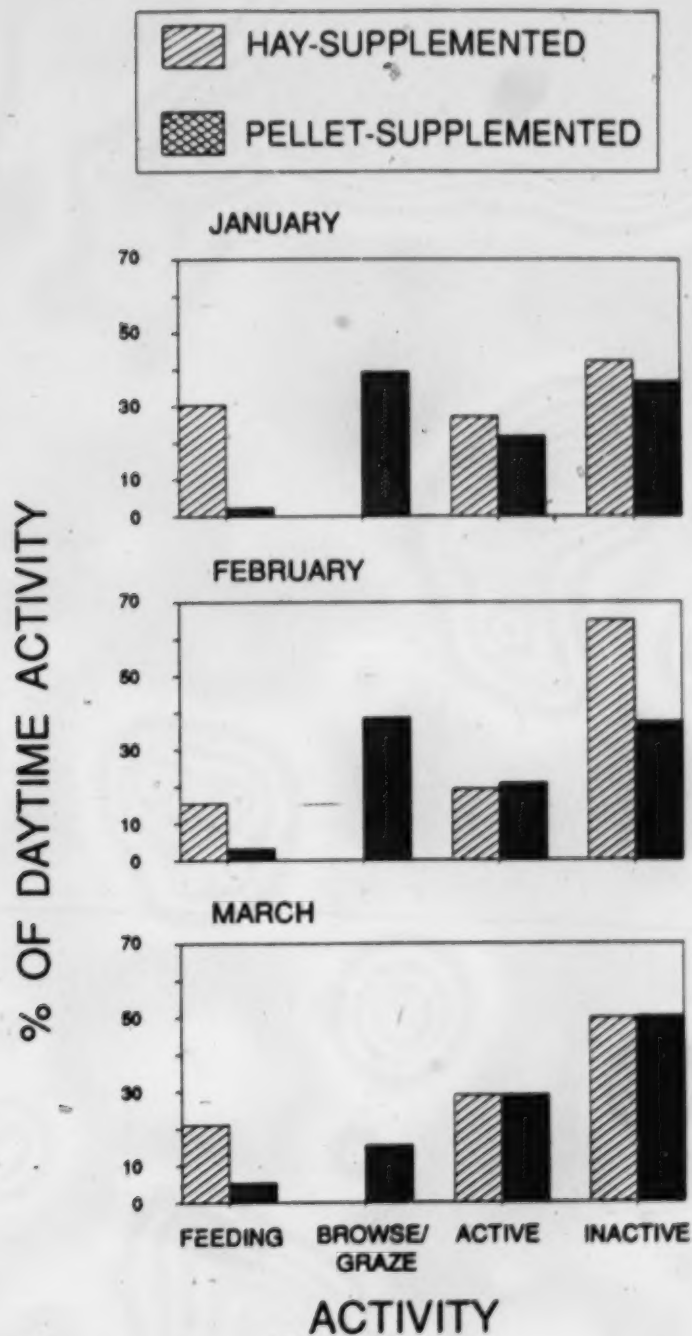


Figure III.3. Percent daytime winter activity of hay- and pellet-supplemented wapiti hinds, winter 1985-86 at M.W.R.S.

D. Discussion

Winter Weights

The different pattern of weight loss between the two years of the study was probably due to the different winter conditions. The winter of 1984-1985 was harsh due to the snow conditions which prevented animals from gaining access to native forage. As a result, they relied heavily on the supplemental feed. The winter of 1985-1986 was considerably milder than the previous winter and natural forage was available throughout the treatment period.

During winter native forage is most limiting. Deer have developed adaptations to deal with winter including reduced demands for growth and production, restricted activities, and a lowered fasting metabolic rate (Short 1981). Winter weight loss is a natural consequence of reduced dietary intake. Overwinter weight loss of up to 30% is common in wild populations of red deer (Mitchell 1972, Moore and Brown 1977). White-tailed deer and black-tailed deer, (Odocoileus hemionus columbianus), lose weight during winter months regardless of the amount of quality or feed offered (French et al. 1956, Bandy et al. 1970), but the degree of weight loss may be tempered by supplemental feeding. Free-foraging adult deer declined 16-20% in weight during winter but supplemented doe white-tailed deer averaged 8% weight loss during this season (Ozaga and Verme 1982). The results from this study showed that pellet-supplemented wapiti hinds gained weight during winter, which agrees with results from Dean et al. (1976) who indicate that wapiti can either maintain

their weight or gain between December and March under feedground conditions.

Supplemental Feed Intake and Weight Change

Decreasing dry-matter intake from December to April is consistent with Westra and Hudson (1981) who found that dry-matter intake in penned wapiti declined from October to April. Estimated intakes of hay and pellets in this study are comparable with, but slightly lower than, measured intakes in penned trials with wapiti conducted at the Ministik Wildlife Research Station (Renecker and Hudson 1988a) and at the University of Alberta Farm (Westra and Hudson 1981). However, this study included two calves in each group (1985-86), which lowered the estimated daily intake per animal. The lower intake of pellets in 1984-85 compared to 1985-86 may be due to a number of factors. The environmental conditions between the two winters was different, the body weights of the hinds were different and supplemental feeding was initiated one month earlier in 1984-85 due to environmental conditions. Any, or a combination of all, of these factors may be responsible for the difference in pellet intakes.

The higher intakes of pellets, compared to hay, may be attributed to the physical form of the diet. Pelleting of feed results in a reduction in particle size due to grinding. This leads to increased density and rate of passage of the diet and, thus, increased intakes (Thorne and Butler 1976). Feeding pelleted alfalfa hay to penned wapiti resulted in a 22 % greater hay intake, 91% faster rate of passage through the digestive tract and 12% lower

digestibility than if baled hay was fed (Thorne and Butler 1976). Mautz and Petrides (1971) reported higher rates of passage in white-tailed deer eating pelleted aspen leaves, sumac inflorescences, and grass clippings than natural feeds that were retained approximately 30% longer. There is also less gastrointestinal fill associated with concentrates, which reduces the pressure on rumen volume and allows for higher intakes (Van Soest, 1982).

Feeding pelleted hay to domestic livestock has been associated with increased feed consumption and weight gains and, increased milk production in dairy cattle (Webb et al. 1957, Weir et al. 1959, Ronning et al. 1959, Meyer et al. 1959, and Cullison 1961).

Increased consumption of pellets compared to baled hay and baled hay plus concentrates has been reported by Meyer et al. 1959, Klosterman et al. 1960, Hopkins et al. 1960, and Lloyd et al. 1962.

Weight differences between the supplemented groups may be attributed to significantly lower ($P < 0.05$) in situ digestible energy and protein content of the hay diet compared to the pellet (see Table II.3). The better performance of the pellet group may also be due to the pelleting process, which leads to increased intakes thus improving gross efficiency (Thorne and Butler 1976, Van Soest 1982).

Activity Budgets

The lower level of natural foraging by the pellet group in March could be attributed to the influence of warm weather. This group was less active and spent more time feeding on supplement than in any other month which suggests an influence of heat stress. Gates (1980)

found that as ambient temperature increases from -31 to +17 °C, mobile activities of free ranging wapiti, in winter coat, decrease from 90% to 45%. This trend in relation to increasing heat has been correlated with decreases in foraging activity and/or feed intake in cattle (Hafez et al. 1969), the African buffalo (Syncerus caffer) (Grimsdell and Field 1976) and moose (Belovsky and Jordan 1978, Renecker and Hudson 1988b). In this study, the increased supplement intake may have compensated for decreased time spent foraging.

This study was based on daytime foraging patterns but, night-time activity must also be considered. Results of the one scan period conducted on a 24-hour basis suggested that foraging patterns did not differ during the night. No foraging behavior was observed by the hay-fed group during the one night scan, although feeding bouts at the feed trough were common. Free-ranging, unsupplemented wapiti have been observed to spend up to 49% of the night engaged in foraging activity during mid and late winter (Gates 1980). Feed intake in the hay group would suggest that if nocturnal foraging occurred the amount of forage consumed would be very low and a small portion of daily feed consumption.

The results of this study indicate clearly that the type and physical structure of supplemental winter feed can have a great influence upon the foraging patterns of captive wapiti. Wapiti supplemented with a pellet diet spent from 15 to 39% of their daytime activity foraging on native vegetation compared to the hay-supplemented wapiti which did not allocate any time to foraging on native range. These results are consistent with Thorne and Butler

(1976) who found that free-ranging wapiti fed pelleted hay spend much more time foraging for native vegetation than do wapiti fed baled or cubed hay.

The overall higher levels of foraging exhibited by pellet-fed wapiti may be a result of fiber deficiencies, because protein and energy were not limiting in the diet. This is evidenced by the maintenance of weight by the pellet group. The lack of grazing/browsing behavior by the hay group indicates the supplement met the dietary requirements of this group. Therefore, the pellet-fed wapiti possibly increased the fiber component of their diet through browsing and grazing. It is not clear whether or not the pellet diet was deficient in total fiber content because processing may have rendered the available fiber into a form unsuitable for optimum digestion by wapiti. Thorne and Butler (1976) found that baled and pelleted hay are similar in fiber content and in vitro dry matter digestibility but have different in vivo digestibilities. They attribute the lower in vivo digestibility of pellets to hay form (finely ground versus long-hay), and its association rate of passage. It is possible that the length of fibers and not total fiber content contributed to the need for additional forage. Lack of ruminal bulk with the pellet diet may also be a cause for increased foraging activity.

Nietfeld (1983) calculated consumption rates for wapiti at Ministik. Wapiti consume 1.8 g/min of browse, forbs, and grass dry matter in all habitats during the winter. Using this value, the pellet fed group consumed an additional 397, 396, and 158 g/head daily of dry matter in January, February and March, respectively.

There is also an energy cost associated with foraging. Hudson et al. (1985) calculate the energy cost of winter foraging to be 6.71 kJ/h. kg^{0.75}. Applying this value, the pellet group expended approximately 1524, 1503, and 600 kJ/head daily of energy, in January, February, and March, respectively, to obtain forage. Using the digestible energy of the pellet (13.60 kJ/g), this translates to 112, 110, and 44 g/head daily of pellets utilized, in January, February and March, respectively, in order to obtain natural forage. The higher intake of the pellet diet may be partially a result of the additional energy requirement of foraging by this group.

In cold environments, increased feeding activity may offset higher thermoregulatory costs (Gates 1980). The ability of the grazing animal to compensate by increasing food intake depends on a number of factors. The availability and quality of forage and the cost of acquiring it are important factors in energy balance. The nutritional condition of the animal is another factor. Ozoga and Verme (1970) found that as deer lose condition, feeding activity is restricted increasingly to warmer parts of the day. White-tailed deer reduce activity in the cold (Silver and Colovos 1957, Banasiak 1961, Day 1963). Moen (1968) suggested that shelter seeking by deer in cold weather may or may not occur depending on nutritional status. He also suggested that when the diet is sufficient to maintain a positive energy balance, the animals may elect not to seek shelter even under highly unfavorable conditions.

Being active in the cold results in a greater heat loss than when

an animal is lying down (Gates and Hudson 1979). Under conditions of forage scarcity and poor quality it could be energetically more favorable to rest and seek shelter rather than to forage under extremely cold conditions. Reduced activity of the pellet fed animals in the cold was not observed in this study suggesting that thermal and nutritional conditions were never critical. The hay fed group maintained similar body condition to pellet fed animals on lower quality and quantities of supplemental feed. Lack of daytime foraging activity by the hay fed group may have served as an energy conserving behavior resulting in similar weights.

Economics of Winter Feeding

One of the major considerations of any winter feeding program is cost. The cost of the pellet was approximately 2.5 times that of hay. Using a value of CDN \$186/tonne for pellets and CDN \$79/tonne for hay, the pellet group cost CDN \$0.96, CDN \$0.98, and CDN \$0.85/head daily to feed compared to CDN \$0.30, CDN \$0.33, and CDN \$0.27/head daily for the hay group in January, February and March, respectively. Although the pellet group did maintain a higher average weight this differential was not significant whereas the cost of feeding was significantly higher. The cost of natural foraging must also be considered. Using the energy cost of winter foraging (Hudson et al. 1985), and the digestible energy of the pellet to calculate the energy cost of foraging, it would take \$.0002/head daily of the pellet ration to supply the energy required to forage during the heaviest foraging month of this study. Thorne and Butler

(1976) calculated that pelleted alfalfa hay costs 21% more per tonne than baled alfalfa, but about 15% less was required for weight maintenance (mostly due to wastage of baled hay on feed grounds). Pelletizing alfalfa does not provide an economic advantage.

In the present study, feed was supplied ad libitum and this resulted in higher feed costs. In New Zealand, pelleted rations are considered an expensive form of feed and are kept for emergency rations and for taming red deer (Yerex 1984).

The objective of a winter feeding program for pregnant hinds is to feed for maintenance and successful reproduction at minimal costs. The results from this study show that to meet this objective, supplementation of farmed wapiti is best accomplished with a hay diet rather than a pellet concentrate diet.

E. Conclusions

Results of this experiment indicate that the level of native range utilization by wapiti can be dramatically affected by the type of supplemental feeding program used. A concentrate diet that is low in fiber content can be used as a management tool to increase the utilization of winter pasture. Conversely, a bulk diet that is high in fiber can be used to minimize range degradation. The two types of diets could also be used in conjunction with each other in order to fine tune range utilization.

Feeding a total pellet diet results in a rapid rate of gastrointestinal passage, which is advantageous in livestock feeding

where quick gains are the objective and feed is relatively unlimited. When feeding wapiti for maintenance and successful reproduction at minimal cost, rapid gastrointestinal passage rate and high intake characteristics of pelleted rations are undesirable. Under these conditions a roughage diet is more suitable. There is a cost associated with using pelleted diets for range management. Feed costs are increased when a concentrate is provided due to higher costs of the ration and increased feed consumption.

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IV. EFFECT OF WINTER NUTRITION ON REPRODUCTIVE PERFORMANCE OF WAPITI HINDS

A. Introduction

Supplemental winter feeding of breeding wapiti hinds must be practical, economical, and result in the production of a calf of optimal weight. Feeding programs also must consider such aspects as conception rates, dystocia, calf birth weights, and calf vitality.

Puberty and fecundity in red deer is highly correlated with body weight; yearling fertility is more severely affected by nutrition than that of adults (Mitchell and Brown 1973, Mitchell and Lincoln 1973, Wegge 1973, 1975, Mitchell et al. 1976, Hamilton and Blaxter 1980, Clutton-Brock et al. 1982). In New Zealand, farmed yearling red deer hinds must reach a target weight of at least 70% of mature liveweight before they can breed successfully (Fennessy 1986). Flook (1970) found that environmental conditions had a greater effect on the development of breeding condition in yearling wapiti than in adults.

Undernutrition of the dam during gestation decreases both birth weight of young in white-tailed deer (Odocoileus virginianus), red deer, wapiti, and beef cattle (Bos taurus) (Verme 1963, Mitchell 1971, Hamilton and Blaxter 1980, Thorne et al. 1976, Wiltbank and Remmenga 1982) and survival of the young (Verme 1963, Mitchell 1971,

Hamilton and Blaxter 1980, Thorne et al. 1976, Corah et al. 1975). Extremely high levels of nutrition prior to calving can also result in problems including difficulty in calving and decreased calf survival, but with no effect on birth weight in beef cattle (Wiltbank et al. 1965, Arnett et al. 1971). A difference in calf birth weight in beef cows receiving high or low planes of nutrition but no difference in calving difficulty has been noted (Bellows and Short 1978, Kroker and Cummins 1979, Wiltbank and Remmenga 1982).

Dystocia rates ranging from 0 to 9% have been reported for red deer hinds in New Zealand (Wilson, 1987). The cause(s) of dystocias in deer is unknown (Wilson 1984), but there is a general consensus that maternal plane of nutrition during the last six weeks of pregnancy and maternal fitness are major factors (Van Reenen 1983, Wilson 1984, 1987, Yerex 1984, Fennessy 1986).

This study was conducted to evaluate the effect of winter nutrition on the reproductive performance of farmed wapiti hinds; specifically, age at first conception, dystocia, and calf vitality.

B. Methods and Materials

Weight Records

Body weights of study animals were measured with an electronic platform scale (Western model no. DF-1000 Accurate Scale Industries,

Edmonton, Alberta, Canada) on a bi-weekly basis. Feed and water were not restricted prior to weighing therefore, body weights included rumen fill.

Birth Parameters

Time of birth and duration of parturition were measured. The initiation of parturition was defined as the time at which the calf's hooves were first visible and the completion of parturition as that time at which the entire calf was free of the hind (Kelly and Whateley 1975). Each hind was fitted with a color-coded identification collar. A 24-hour watch was maintained by two alternating observers from May 1 to July 15 of each calving season. Observations were made at distances of 10 - 50 meters with the aid of binoculars.

Calf vitality was assessed as the length of time from calf drop to first standing and to first suckling (Kelly and Whateley 1975). Birth weights were obtained after the first suckling.

Calf measurements were obtained according to Ruttle et al. (1982) using calipers and a rule. Linear measurements consisted of head width, at the temporal region of the mandibular joint; shoulder width, at the widest point on the spine of the scapula; and hip width, measured as the distance between the tuber coxae. In addition, width of the incisor bar and length of the metatarsal were measured.

Weight at First Conception

Data compiled at the Ministik Field Station from 1982-1986 were used to determine the weight at which first conception took place. A total of 16 hinds were used in the analysis. Weights of animals taken during October were used in the analysis.

Statistical Analysis

Parturition length, birth weights, calf vitality and weight at first conception were analyzed using Student-t Tests (for independent samples) (Anon. 1985a). Calf birth weight was correlated on body measurements using a correlation matrix (Anon. 1985a). Calf birth weight measurements were correlated on October hind weight and were analyzed using multiple linear stepwise regression (Anon. 1985b). Records on 39 hinds from the Ministik Field Station from 1982 - 1986 were used in the analysis.

C. Results

Maternal Behavior

Calving dates for wapiti were not synchronous and spanned a 3 to 4 week period. Calving took place from May 14 to June 15 in 1985 and from May 12 to June 8 in 1986. During late pregnancy, the hinds spent much time resting. Most hinds became restless and separated from the herd immediately prior to calving. They exhibited a distinct fence-pacing behavior 24-48 hours prior to calving and most began to vocalize as parturition approached. Behavioral changes

sometimes occurred and some hinds became quite aggressive during this period. During the last few days prior to calving, the udder began to fill considerably and the vulva swelled slightly. The hinds eventually stopped pacing and settled in a particular area. The appearance of the amniotic sac was usually the first definite indication that calving was in progress. The amniotic sac was immediately followed by the presentation of the legs of the calf. Once the legs were presented, the hind frequently alternated from standing to lying or rolling laterally with legs extended. During strong contractions, the hind was in obvious discomfort and frequently "yawned", as she strained, with neck stretched forward, ears back, and mouth open. The majority of calving (95%) took place during daylight. The hinds were sometimes alone and sometimes near others when they calved.

Hinds with difficulty calving showed various features that deviated from the normal calving sequence. Occasionally the amniotic sac would appear with the legs of the calf presented and the hind would strain for an hour or two with no progress and then return to grazing or standing in the paddock. This behavior was typical of cases of fetal oversize or reverse presentations. Calving difficulty was suspected when only one leg of the calf emerged, the head or posterior end of the calf only emerged, or the hind legs emerged.

Calving Success

Table IV.1 summarizes the results of the 1985 and 1986 calving seasons. There was no significant difference ($P > 0.05$) in

Table IV.1. Calving summary for wapiti at M.W.R.S, 1985 and 1986.

	Unsupplemented Group			Supplemented Group*		
	1985	1986	Total	1985	1986	Total
Number of Hinds	4	6	10	8	14	22
Number of Conceptions	3	5	8	7	10	17
Number of Calves	2	5	7	7	10	17
Perinatal Mortality	0	0	0	0	1	1
Abortions	1	0	1	0	0	0
Abnormal Presentation	1	1	2	2	1	3
Assisted Births	0	1	1	2	1	3
Lactation Failure	0	0	0	3	0	3
Calf Rejection	0	0	0	0	1	1
Calves Weaned	2	5	7	4	8	12

* Hay- and pellet-supplemented hinds combined.

conception rates between the unsupplemented and supplemented (hay and pellet) groups. Only one adult hind failed to conceive in the two years of the study, the remaining failed conceptions occurred in two-year-olds.

One case of perinatal mortality was observed. The calf, weighing only 10.5 kg, was born to a sub-adult (2 year old) in the supplemented group. One abortion, from unknown causes, occurred in the unsupplemented group during February 1985.

Abnormal presentations occurred on two occasions in the unsupplemented and three times in the supplemented groups. These births consisted of calves presented backwards or backwards and upside down. Assistance during calving had to be provided on one occasion in the unsupplemented group to a backwards calf and on three occasions to hinds in the supplemented groups. Abnormal presentation was involved in two cases and normal presentation in one case. One incidence of calf rejection was observed in a hind from the supplemented group.

Lactation failure after calving occurred on three occasions in the supplemented groups and was absent in the unsupplemented group. Lactation failure is generally associated with prolonged negative energy balance which usually occurs during late winter and spring (Denholm 1984), but in this instance occurred in hinds experiencing a positive energy balance during this period.

All calves born to hinds in the unsupplemented group survived to weaning over the two year period. In the supplemented groups, 12 of the 17 calves were weaned. Calf mortality in the supplemented groups was due mainly to lactation failure.

Parturition Length, Birth Weight, and Calf Vitality

Pre-parturition weights of hinds, parturition length, and calf birth weights, for the unsupplemented and supplemented (hay and pellet) groups, were not significantly different ($P > 0.05$), over the study period (Table IV.2). The mean ($\pm$ S.D.) pre-parturition weights for the pasture and supplemented groups respectively, were 264 ± 16 kg and 273 ± 9 kg. The mean ($\pm$ S.D.) parturition length for the unsupplemented and supplemented groups respectively, was 30 ± 10.81 minutes and 45 ± 3.8 minutes.

The mean ($\pm$ S.D.) birth weight of calves in the unsupplemented group was 18.4 ± 1.14 kg while calves from supplemented hinds weighed 16.9 ± 0.54 kg. No significant difference ($P > 0.05$) was found between the birth weights of male and female calves or the number of males and females born to each group (Table IV.2).

Table IV.3 summarizes the results of calf vitality after parturition. When assisted births were included in the analysis no significant difference ($P > 0.05$) was found between the unsupplemented and supplemented groups, even though the means differed widely. Considerable variation around the means probably contributed to the lack of significance. The time to standing and suckling of calves from supplemented and unsupplemented hinds was not significantly different ($P > 0.05$).

No significant difference ($P > 0.05$) existed between the supplemented and unsupplemented groups when the assisted births were removed from the analysis (Table IV.3). The mean ($\pm$ S.D.) time to standing was 36 ± 5.34 minutes and 34 ± 6.41 minutes, for the

Table IV.2. Mean $\pm$ SD parturition length, birth weights, hind weights, and number and sex of calves from unsupplemented and supplemented (hay and pellet) hinds during the 1985 and 1986 calving seasons at M.W.R.S.

	Unsupplemented		Supplemented	
	Mean	SD ^a	Mean	SD ^a
Mean Parturition Length (min)	30.00 (5) ^b	24.17	44.87 (8)	10.81
Pre-Parturition Hind Weight (kg)	264.26 (6)	39.80	273.18 (13)	30.68
Mean Birth Weight (kg)	18.43 (6)	2.81	16.99 (15)	2.08
Number of Male Calves	5		9	
Number of Female Calves	2		8	

^a Standard deviation of the mean.

^b Number in parentheses is the number of samples.

Table IV.3. Mean $\pm$ SD time to standing and suckling of assisted and unassisted births of calves from unsupplemented and supplemented (hay and pellet) hinds during the 1985 and 1986 calving seasons at M.W.R.S.

Activity	Unsupplemented		Supplemented	
	Mean	SD ^a	Mean	SD ^a
Assisted Calves Included				
Mean Time to Stand (min)	34.50 (6) ^b	11.02	66.00 (11)	67.26
Mean Time to Suckle (min)	63.85 (6)	23.98	71.10 (11)	52.15
Assisted Calves Excluded				
Mean Time to Stand (min)	35.60 (5)	11.95	33.98 (8)	18.31
Mean Time to Suckle (min)	62.00 (5)	26.34	56.65 (8)	20.92

^a Standard deviation of the mean.

^b Number in parentheses is the number of samples.

unsupplemented and supplemented groups respectively. The mean ($\pm$ S.D.) time to first suckling was 62 ± 11.78 minutes and 57 ± 7.40 minutes, for the unsupplemented and supplemented groups respectively. Suckling prior to standing was noted on one occasion in this study.

The mean time to standing was significantly different ($P < 0.05$) when calves from assisted and unassisted births were compared (Table IV.4). Assisted calves are less vital at birth in comparison to calves from normal parturitions. The mean time to suckling for assisted calves was almost twice that of normal parturitions and approached significance ($P = 0.09$), but was highly variable. There was also a trend towards more difficult parturitions in the supplemented groups.

Calf Birth Weight and Linear Dimension

Birth weight was highly correlated ($P < 0.01$) to all calf linear measurements (Table IV.5). Stepwise multiple linear regression provided the following equation:

$$y = -11.288 + 0.197 (x_1) + 0.0458 (x_2)$$

where: y - Calf Birth Weight (kg),

x_1 - Hip Width (mm),

x_2 - Shoulder Width (mm),

$r^2 = 0.7615$,

$P < 0.001$

Table IV.4. Mean $\pm$ SD time to standing and suckling of calves from assisted and unassisted births during the calving seasons, 1985 and 1986, combined at M.W.R.S.

Activity	Assisted Births		Unassisted Births	
	Mean	SD ^a	Mean	SD ^a
Mean Time to Stand (min)	120.8 (4) ^d	89.60	34.6 ^b (13)	15.59
Mean Time to Suckle (min)	100.5 (4)	76.61	58.3 ^c (13)	22.23

^a Standard deviation of the mean.

^b ($P < 0.01$)

^c ($P < 0.05$)

^d Number in parentheses is the number of samples.

Table IV.5. Sample r-correlation coefficients among various measurements of calf body size and calf birth weight from wapiti calves at M.W.R.S.

Item	Birth Weight	Head Width	Shoulder Width	Hip Width	Metatarsal Length
Head Width	0.64 ^a	--	--	--	--
Shoulder Width	0.59 ^a	0.21	--	--	--
Hip Width	0.81 ^a	0.60 ^a	0.38	--	--
Metatarsal Length	0.69 ^a	0.36	0.30	0.69 ^a	--
Incisor Width	0.51 ^a	0.29	0.36	0.46 ^b	0.36

^a (P < 0.01)

^b (P < 0.05)

Calf Birth Weight

No significant treatment differences ($P > 0.05$) in birth weights could be detected. Therefore, data collected from all hinds that had calved between 1982 and 1986 were pooled to explore relationships among hind age, October hind weight, April hind weight and calf birth weight. A stepwise multiple linear regression equation was developed identifying the significant variables, October hind weight and age of hind. There was no significant relationship ($P > 0.05$) between April hind weight and calf birth weight. The following equation predicted calf birth weight from October hind weight and age of hind:

$$y = 5.445 + 0.430(x_1) + 0.0361(x_2)$$

where: y - Calf Birth Weight (kg),

x_1 - Age of Hind (years),

x_2 - October Weight of Hind (kg),

$r^2 = 0.4686$, $P < 0.001$,

$n = 39$

Age at First Conception

Age at first conception was variable at the Ministik Field Station during the years 1982 to 1986. Fifty-six percent of hinds 1.5 years of age successfully conceived and the remainder at 2.5 years of age or later. Hind weight during the rut in October seems to be a better indicator of first conception than is age. A significant difference ($P < 0.05$) was found between the mean weights

of hinds 1.5 years of age and older that conceived for the first time and those that did not. Hinds achieving an October mean ($\pm$ S.D.) target weight of 228 ± 8.06 kg conceived while hinds with an October mean ($\pm$ S.D.) weight of 201 ± 6.47 kg did not. Table IV.6 shows the relationship between October hind weight and pregnancy rate in first-parity hinds 1.5 to 2.5 year of age. No conception took place in hinds under 195 kg. A conception rate of 100% in hinds over 226 kg dropped to 50% in hinds 196 to 225 kg.

D. Discussion

Calving Success

In general, the behavior of wapiti hinds while calving was similar to that of red deer (Arman et al. 1978, Wilson 1984), except that the amniotic sac was followed immediately by the legs unlike red deer where the amniotic sac may appear up to four hours before birth (Wilson 1984). Perinatal calf mortality and an abortion were both observed in this study. Chances for calf survival fall below 50 percent when birth weight is below 11.4 kg (Thorne et al. 1976). It is possible that the abortion was a result of a loss in body condition, because the unsupplemented group underwent weight losses of 11% by February. Thorne et al. (1976) observed three aborted fetuses in a group of wapiti hinds that had lost over 15% of their body weight. Severinghaus and Cheatum (1956) reported that white-tailed deer are more likely to resorb a fetus during

Table IV.6. Relationship between mating weight in October and pregnancy in first-parity hinds at M.W.R.S.

Liveweight (kg) at mating	Pregnancy Rate	
	%	N
176 - 195	0	0 / 2 ^a
196 - 205	50	2 / 4
206 - 215	50	2 / 4
216 - 225	50	1 / 2
226 - 235	100	1 / 1
236 - 245	100	1 / 1
> 246	100	2 / 2

^a Number of hinds pregnant / number of hinds in weight class.

malnutrition than are domestic ruminants. Although conception rates were not reported, Verme (1967) states that white-tailed deer subjected to restricted dietary intake produce fewer fawns than those on higher planes of nutrition.

Abnormal presentations and posterior presentations are very common among farmed red deer and are factors contributing to dystocias (Wilson 1984). Calf rejection by the hind has also been noted on red deer farms in New Zealand where the hinds refuse to accept their offspring that ultimately starve (Wilson 1984). Denholm (1984) suggests that poor body condition of the hind may result in failure to establish the maternal bond. Interference with the calf, excessive observation, and handling of the calf have been suggested as causes of calf rejection (Wilson 1984).

The cause for lactation failure after calving in this study was not established, but would appear to be linked to type and amount of supplemental feed, because it only occurred in hinds fed the alfalfa/barley pellet. Arman et al. (1978) report lactation problems in young red deer hinds fed a barley-based ration at 0.5 kg/head during the calving period. Lactation failure of this type has been noted in reindeer (Rangifer tarandus tarandus) fed high barley rations (R.G. White pers comm 1985). Blanchard and Hauer (1986) found that reproductive performance of reindeer is severely impaired when their diet was composed of whole-grain barley. Eighty-five percent of the reindeer consuming all-barley rations became pregnant, however, 76 percent of the pregnancies resulted in stillborn calves as a result of malpresentation of the fetus. They speculate that the

reproductive failure is most likely a result of disfunction in rumen and/or carbohydrate metabolism. A similar mechanism may also affect milk production of wapiti hinds fed high-barley rations, however, more research is needed.

Parturition Length, Birth Weight and Calf Vitality

Hinds from the unsupplemented group seemed to have compensated for over-winter weight loss, from the end the trial in April to the time of parturition. This compensatory intake, during the spring green-up period (Hudson and Watkins 1985), may account for the similar pre-parturition weights, parturition lengths and calf birth weights.

The mean parturition length for the unsupplemented and supplemented groups compare favorably with parturition lengths from free-ranging tame red deer in Scotland and New Zealand. Arman et al. (1978) report a mean parturition length of 45 minutes while a shorter parturition length of 21 minutes was determined by Kelly and Whateley (1975). Parturition lengths in white-tailed deer are 20 - 22 minutes, for the first fawn, with mean interval between first and second birth of 24 minutes (Townsend and Bailey 1975). Parturition length in wapiti is similar to other cervids and falls within the normal range reported for domestic cattle (Jainudeen and Hafez 1980).

The male calves in this study were 1.86 kg heavier than females, which compares favorably with the 1.16 kg difference noted by Johnson (1951) for free ranging wapiti. Births weight for male red deer calves are 0.5 kg higher than for females (Clutton-Brock et al. 1982). Mitchell (1971) demonstrated a significant difference in

birth weight between male and female red deer calves in Scotland (but notes that it takes a large sample size to show significant differences).

The mean time to standing for the unsupplemented and supplemented groups compares favorably to the mean standing time of 35 minutes determined by Kelly and Whateley (1975) for captive red deer in New Zealand. Arman et al. (1978) report a slightly longer mean time to standing of 47 minutes for red deer calves in Scotland. First suckling for red deer calves in New Zealand and Scotland occurs at 45 minutes and 33 minutes respectively (Kelly and Whateley 1975, Arman et al. 1978). The mean time to first suckling, for wapiti calves in this study for the unsupplemented and supplemented groups are considerably longer than the suckling times reported for red deer. In another study, Arman (1974) reports a mean time to first suckling of 78 minutes for red deer calves in captivity. She suggests that more rapid post-natal development is achieved by larger calves being born to larger hinds.

Arman et al. (1978) notes a large number of calves suckling prior to standing. This behavior was noted on one occasion in this study and was not recorded by Kelly and Whateley (1975) and only on one occasion by Arman (1974). The majority of hinds used by Arman et al. (1978) were first-time calvers. It is possible that more experienced hinds rise sooner after parturition thus not affording the opportunity to suckle until after the calf stands. Alternatively, wapiti calves may actually take more time to suckle than red deer calves.

The mean time to suckling for assisted calves, in this study, was

almost twice that of normal parturitions. These results clearly indicate that calves experiencing a difficult parturition are much less vital than those from normal parturitions. The trend towards more difficult parturitions in the supplemented groups suggests that over-supplementation during winter may lead to calving difficulty and reduce calf vitality. Studies in New Zealand have shown that over-fatness in red deer hinds can contribute to calving difficulty (Van Reenen 1983, Wilson 1984, Yerex 1984).

Calf Birth Weight and Body Size

Birth weight was highly correlated to all calf linear measurements. Ruttle et al. (1982) found that head width and shoulder width are significantly correlated to calf birth weight in beef cattle, but hip width is not. Results from this study indicate that entire calf body size increases as calf birth weight increases. Therefore, it is reasonable to conclude that it is calf size and not calf condition that contributes to higher birth weights.

Birth weights of conventional farm livestock are affected by nutritional factors operating on the female during pregnancy (Mitchell 1971). Genetic factors, maternal age and weight as well as nutrition are found to be of importance for calf birth weight, growth and survival (Bergerud 1975, Albon et al. 1983, Rognmo et al. 1983). The results from this study demonstrate that the weight of wapiti hinds at the time of conception and age of the hind are factors determining calf birth weight. Hind weight in late pregnancy (April weights) proved to be of no value in predicting calf birth weight. A

similar relationship between birth weight and weight of the hind at the time of the rut (autumn weight) for red deer has been reported by Blaxter and Hamilton (1980). Blaxter and Hamilton (1980) found no effect of age of hind on calf birth weight that could not be explained by hind body weight. Birth weight of reindeer calves was found to correlate with maternal weight the previous autumn (Eloranta and Nieminen 1986). Birth weight of reindeer calves was found to correlate with maternal age as long as the body condition of hinds did not deteriorate with age (Skogland 1984). Maternal age and calf weight are also found to correlate among Norwegian semi-domestic reindeer (Lenvik and Bo 1983).

The relationships developed, between calf birth weight and age and weight of the hind, by various researchers and the present study may be a result of the particular nutritional regime used in the study. The plane of nutrition during pregnancy greatly affects reproduction in domestic ruminants (Bond and Wiltbank 1970) and white-tailed deer (Verme 1965). Thorne et al. (1976) demonstrated that weight loss in wapiti during pregnancy is significantly and directly correlated to calf weights at birth and at 4 weeks of age. Wapiti hinds that lose no weight during the winter and spring months have the heaviest calves at birth, whereas those that lose at least 6.6 percent of their weight produce the smallest calves. In the present study no significant difference was noted between wapiti hinds that underwent over-winter weight loss and those that did not. This is probably due to both groups having equal access to spring forage resources 4 to 6 weeks prior to calving, thus providing adequate nutrition through late gestation.

Age at First Conception

Age at first conception for wapiti hinds at the Ministik Field Station compares favorably to Hamilton and Blaxter (1980) who found that 41% of red deer hinds breed at 16 months of age. Wapiti are seasonal breeders. Stags compete for groups of hinds and mating takes place in October and November with hinds calving the following May through July. Red deer hinds first conceive about 16 months of age and calve at 2 years of age at the earliest (Hamilton and Blaxter 1980). Blaxter et al. (1974) conclude that it is unlikely that hinds can be induced to breed at 5 months of age. Flook (1970) in a study of age-specific pregnancy rates in free-ranging wapiti found no pregnant calves and a highly variable pregnancy rate among yearlings (0 to 78 percent) even in samples taken in the same area in different years. Flook (1970) concluded that development of breeding condition is more subject to the effects of environmental conditions in yearling than in adult females. The results of Flook (1970) and the present study, are consistent with Hamilton and Blaxter (1980) who found that whether or not a red deer hind becomes pregnant in Scotland depends entirely on her weight during the rut. A similar relationship was found in red deer in New Zealand (Fennessy 1986) where a hind must be at least 70 kg to reach puberty and successfully breed, which is about 70 percent of the mature liveweight.

E. Conclusions

Winter weight loss of up to 15 percent of autumn weight did not

adversely affect calving performance. Overfeeding pregnant hinds on high-barley rations during the winter adversely affected milk production and may have contributed to some cases of calving difficulty. Overwinter weight losses in pregnant wapiti hinds of 10 percent of autumn weight are allowable providing adequate nutrition is provided during the last trimester of pregnancy. Calves from assisted births were less vital at birth than those from natural births. Calf birth weights were correlated to linear body measurements indicating that it is the overall size of the calf contributing to birth weight and not fat reserves of the calf. Calf birth weight can be predicted from the October weight of the hind as she enters the rut. Wapiti hinds must reach a mean target weight of 228 kg in order to breed for the first time. Further research is needed to investigate the effects of barley rations on the lactation performance of cervids.

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V. MILK PRODUCTION AND CALF GROWTH OF FARMED WAPITI

A. Introduction

Each winter, wapiti are subjected to varying degrees of nutritional deprivation that are believed to influence subsequent lactation and calf performance. Lactation occurs at a nutritionally favorable time of year when digestible vegetation is lush and abundant, but hinds may need to rebuilding tissue reserves lost through the winter. An important question is whether hinds that have suffered greater winter weight loss make smaller investments in their calves by reducing milk production in order to improve conception rates the following autumn (Clutton-Brock et al. 1982).

Milk production of beef cows is closely associated with nutritional status. Bond and Wiltbank (1970) found that beef heifers on a low energy or low protein diets weigh less and give less milk than heifers on high energy levels during the first lactation. They also noted that the level of energy that the heifer receives significantly affected the growth of first calves. Swanson and Hinton (1964) found that dairy heifers reared on a subnormal feeding regimen produce less milk than their twins which were fed normally. Milk yields have also been shown to influence weaning weights of beef calves (Butson et al. 1979).

Several studies suggest that this is so in the closely related red deer. Arman et al. (1974) found that red deer hinds on a low plane of nutrition produce less milk than hinds on a high plane. Loudon et al. (1984) found that hinds grazed on improved species pastures produce more milk than hinds grazed upon indigenous hill pasture. Watkins et al. (1985) showed that previous nutritional history also affects milk production; wapiti hinds which are supplementally fed during winter showed a trend towards producing more milk than those which are free ranging.

The objectives of this study were to: 1) compare the production and composition of milk from hinds experiencing various degrees of winter weight loss (manipulated by winter feeding), 2) evaluate milk consumption and calf growth, 3) evaluate the adaptive response of calves to varying milk supplies.

B. Methods and Materials

Milk Production and Composition

Milk production was measured by two techniques: 1) suckling and 2) hand milking. Milk consumption was measured on a bi-weekly basis, from June 1985 to September 1985, utilizing the suckling technique. Following a morning suckling bout, six calves were separated from hinds for six hours at which time calves were diapered, weighed, and then allowed to suckle. During the separation period the hinds were allowed access to pasture and water.

The calves were denied access to feed or water during the separation period to ensure an eagerness to suckle when they rejoined the hinds. After suckling, the calves were weighed again and the weight difference attributed to volume of milk consumed. The procedure was repeated after an additional six hours. The diaper was used to eliminate any chance of weight loss occurring through urination or defecation. There is a tendency, especially in young calves, to defecate or urinate as a response to being licked by the dam while suckling (Arman 1974). The diapers were made from feed sacks with holes cut for the legs. A disposable baby diaper was fitted on the inside of the feed sack to absorb urine. Each calf was fitted with a separate diaper to avoid scent transfer between calves. The values obtained from the two trials on the same day were averaged to obtain a value for 6 hour milk production which was then extrapolated to 24-hour milk production. Weight of milk consumed, and duration of the suckling bout were recorded.

Milk production and composition was measured monthly from July to October (1985) by hand-milking. Five hinds were separated from their calves in the morning and were milked using teat cannulae and an intramuscular injection of 20-40 IU oxytocin (Dominion Veterinary Laboratories, Winnipeg, Manitoba) followed by hand stripping. The procedure was repeated following a six hour separation during which time hinds were allowed access to feed and water. The volume of milk measured after the second milking was used to calculate six hour milk production values and was then extrapolated to 24-hour milk production.

Milk samples collected during the second milking were analyzed for fat, protein, and lactose content at the Alberta Milk Testing Laboratory, Edmonton, Alberta, Canada. Energy content was then calculated using a formula that was determined by Perrin (1958). Fatty acids were measured from milk samples taken from the second hand milking on each day of the last three milkings. Fat was extracted from milk by the Roese-Gottlieb method and fatty acids analyzed according to Cadden and Kennelly (1984).

From May 1 to September 1, 1985, eight hinds, and later six calves, were maintained in a 5 ha enclosure. The hinds had access to native pasture and were supplemented ad libitum with a pelleted feed (Table II.2) for the duration of the milk study.

Calf Behavior

Five dawn-to-dusk (16 hour) activity scans of the calves were conducted bi-weekly from June 1985 through August 1985. Six cow-calf pairs were observed and the calves were marked at birth with identification collars for behavioral observations. Two observers alternated during the observation periods. All observations were made at distances of 10 - 50 m with the aid of 7 X 35 binoculars. In addition to duration of suckling by the calf, three categories of calf behavior were recorded: 1) active (non-feeding) included activities such as walking, running or play (excluding grazing or browsing), 2) inactive included any behavior that required little or no energy expenditure such as lying, or lying ruminating, and 3) foraging included the consumption of pasture or supplemental feed.

Data were collected by instantaneous sampling at 10 minute intervals (Jacobson and Wiggins 1982) on general behavior, whereas continuous time sampling (Lehner 1979) was used to for suckling durations. A nursing bout was judged successful if the calf maintained contact with the udder for at least ten seconds.

Calf Weights

All calves were weighed weekly on an electronic scale (Western model no. DF-1000 Accurate Scale Industries, Edmonton, Alberta).

Statistical Analysis

Least squares analysis of variance was used to analyze milk volume and composition from both milking techniques (Harvey 1964). The data were adjusted, by extrapolating between data points, to bring each hind to the same day of lactation prior to analysis. Analysis of variance was used to evaluate differences in fatty acid composition between groups, calf growth rates, calf activity and suckling data (Anon. 1983). The data from calf activity and suckling were adjusted to bring the calves to similar ages. Linear regression analysis was used to correlate calf age to weight (Anon. 1985).

C. Results

Milk Production

The results of the two milk estimation techniques, for the unsupplemented and pellet groups, are shown in Fig. V.1.

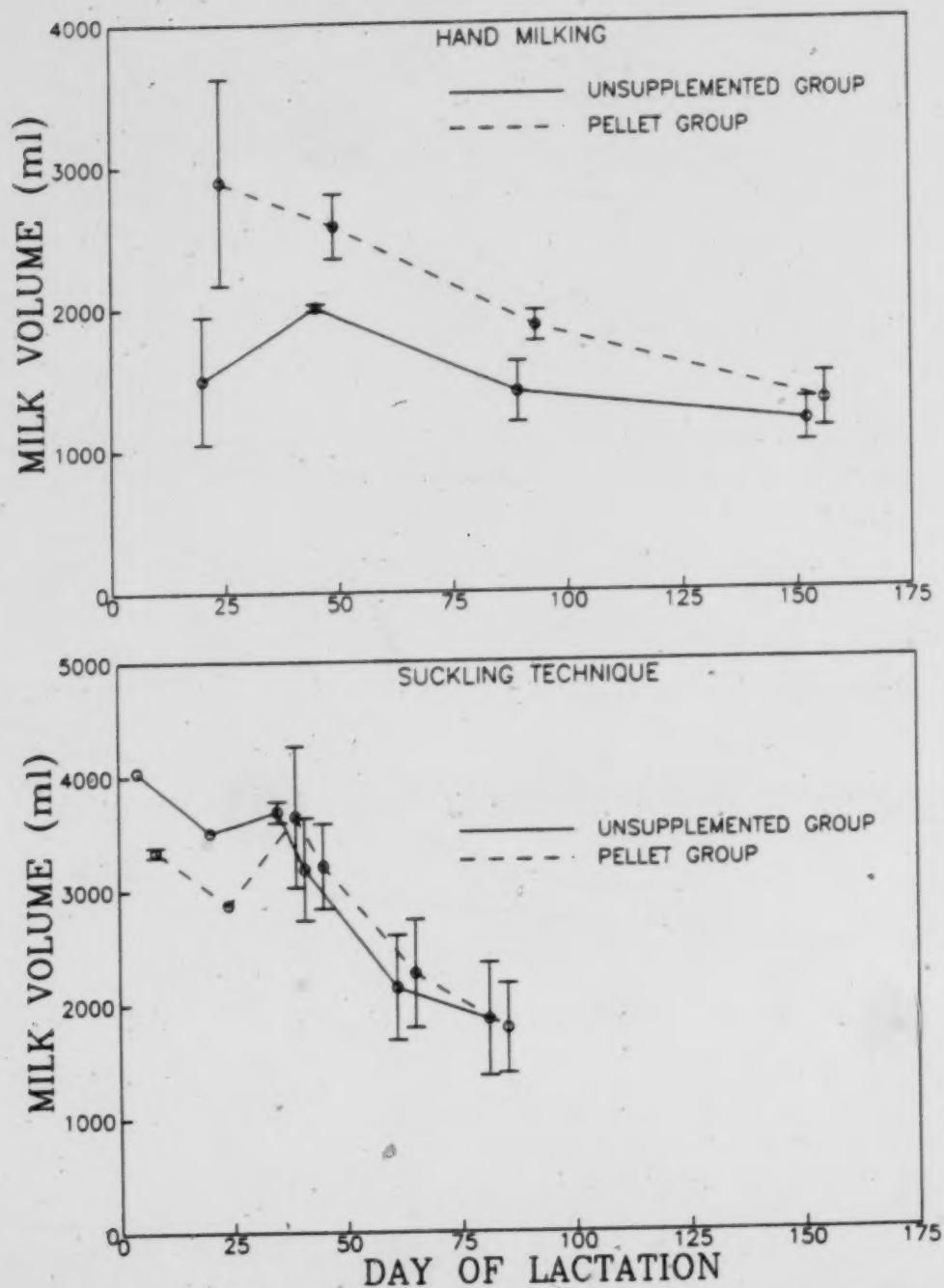


Figure V.1. Mean $\pm$ SE milk volume from winter unsupplemented and pellet-supplemented wapiti hinds at the M.W.R.S.

The results from the hand milking technique showed a significant difference ($P < 0.05$) between the volume of milk produced by the unsupplemented and pellet group. The pellet group produced a higher volume of milk during all stages of lactation.

The peak daily volume of lactation was also different between the two groups. The pellet group showed a peak volume of 2962 ml early in lactation (day 22) compared to the unsupplemented group which peaked at 2575 ml later in lactation (day 47).

The results from the suckling technique proved much more variable than hand milking; no significant treatment differences ($P > 0.05$) were detected. The volumes were higher than those estimated by hand milking during the early part of lactation (up to 50 days), but were similar to estimates from hand milking for the latter stages of lactation. No significant differences ($P > 0.05$) were detected in the length of the suckling bout or the rate at which milk was ingested between the unsupplemented and pellet groups (Fig. V.2). A high degree of variability existed in both the suckling rates and bout length parameters.

Gross Composition of Milk

No significant difference ($P > 0.05$) was found in the concentration of protein, fat or lactose in the milk of hinds from the pellet and unsupplemented groups (Fig. V.3). The unsupplemented group tended to have slightly higher milk fat and protein levels while the pellet group tended to have higher lactose levels. Milk energy (kJ/g) was not significantly different ($P > 0.05$) between the

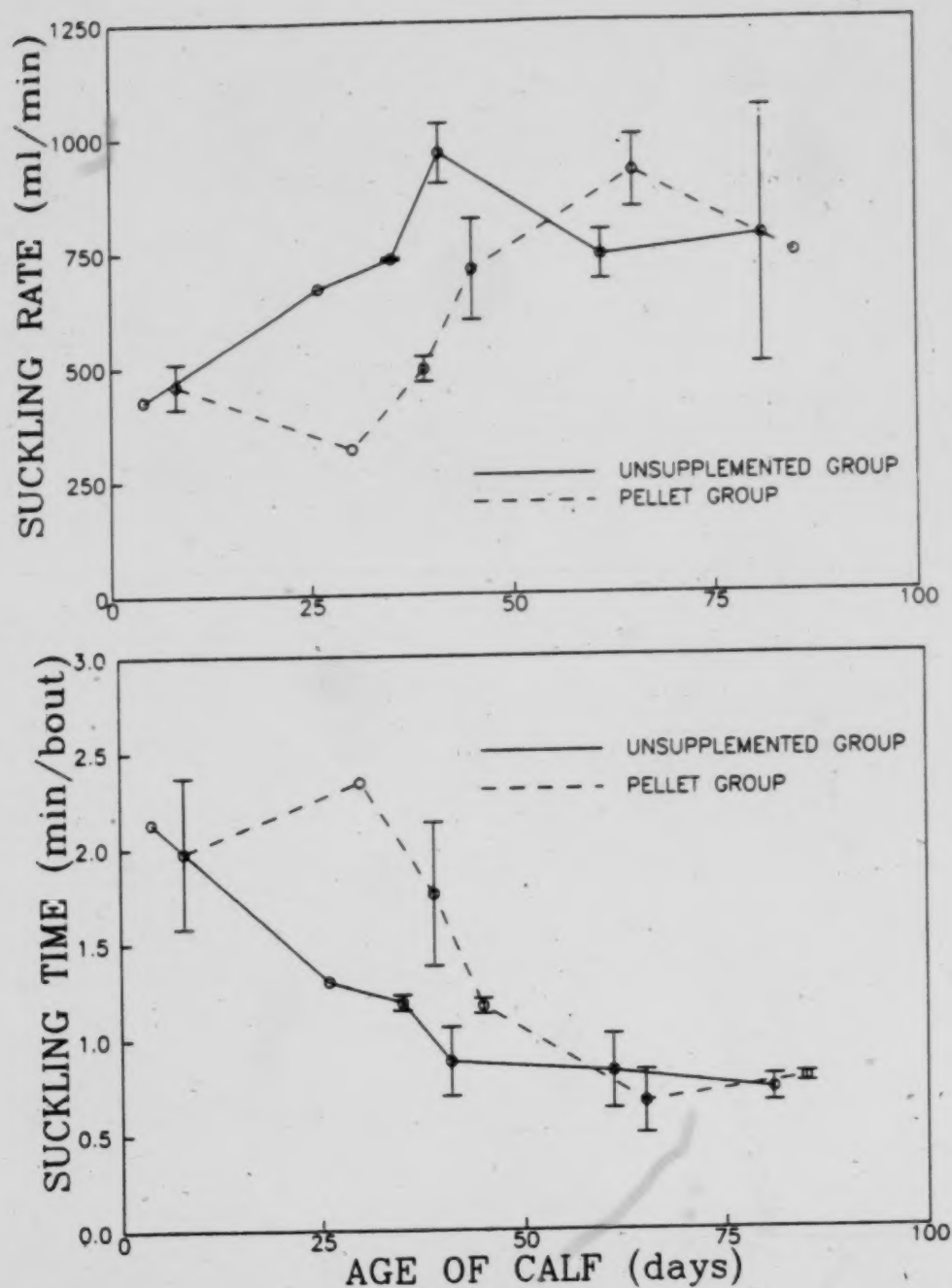


Figure V.2. Mean $\pm$ SE suckling rates and bout lengths (as determined by the suckling technique) of wapiti calves from winter pellet-supplemented and unsupplemented hinds at M.W.R.S.

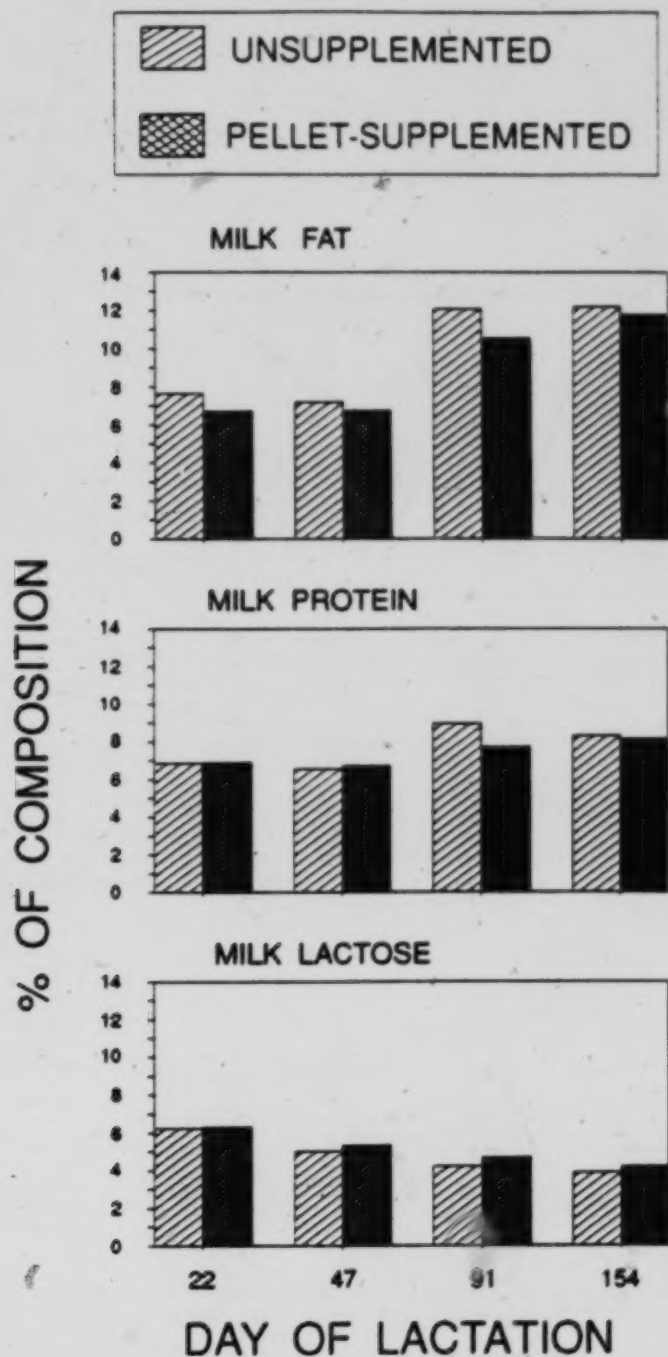


Figure V.3. Gross milk composition from pellet-supplemented and unsupplemented wapiti hinds at M.W.R.S.

unsupplemented and pellet groups. The mean value, for milk energy, over the 150 day lactation was 6.4 kJ/g for the pasture and 6.0 kJ/g for the pellet group.

Even though individual constituents and energy concentration did not differ between the treatment groups, daily milk energy yield was significantly higher ($P < 0.05$) in the pellet group (Fig. V.4), reflecting a significantly higher volume of milk. The greatest differential existed during the early stages of lactation, but continued throughout lactation. As a result, calves from dams in the pellet group received more milk energy per day than their counterparts in the unsupplemented group.

Milk Fatty Acid Composition

Significant differences ($P > 0.05$) in the proportions of individual fatty acids between the pellet and unsupplemented group were detected only in fatty acid C18:1. The unsupplemented group had a higher concentration of C18:1 at all stages of lactation (Table V.1).

There were no significant differences ($P > 0.05$) in the proportion of short chain (C4:0 - C15:0) and long chain (C16:1 - C18:3) fatty acids between the pellet and unsupplemented groups. A significant difference ($P < 0.05$) was detected in chain length over time. In both groups, long chain fatty acids declined through lactation but increased on day 154 of lactation. Short chain fatty acids were more prevalent at the beginning of lactation and declined throughout lactation with the lowest values at day 154.

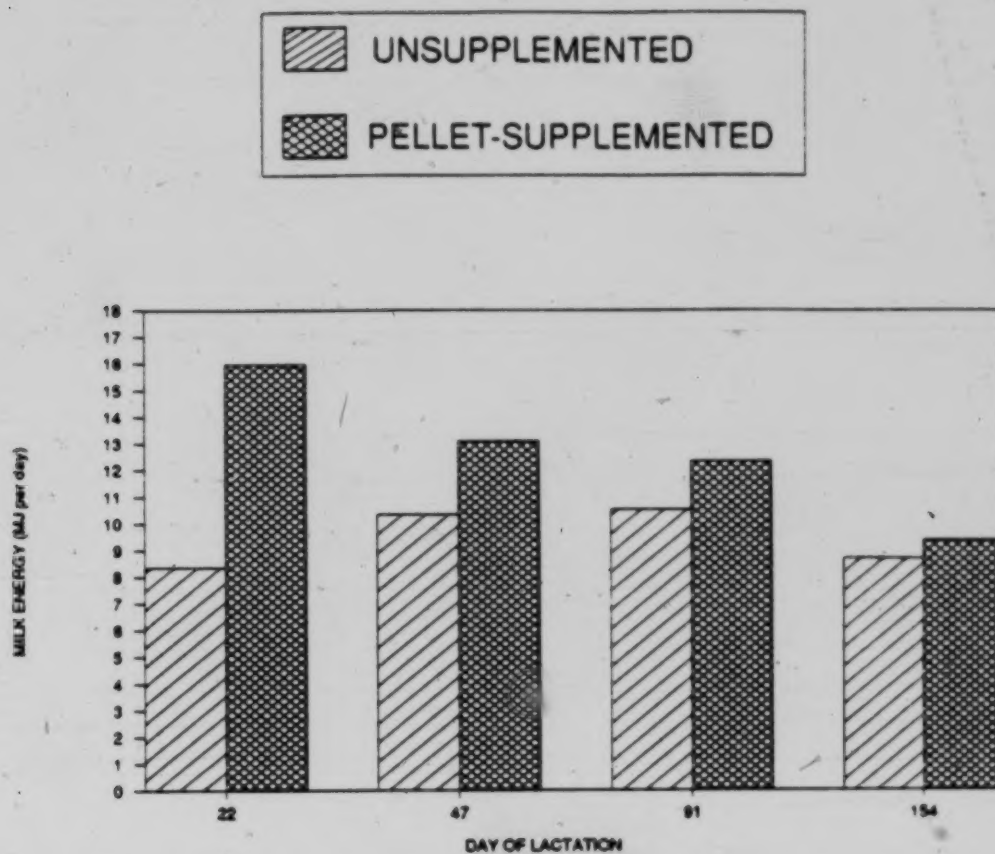


Figure V.4. Mean milk energy per day (MJ) from winter unsupplemented and pellet-supplemented wapiti hinds at M.W.R.S.

Table V.1. Mean $\pm$ SE proportions of fatty acids in the milk fat of winter unsupplemented and pellet-supplemented wapiti at 47, 91, and 154 days of lactation at M.W.R.S.

Fatty Acid	Day of Lactation					
	47 ^a		91 ^b		154 ^a	
	Unsuppl.	Pellet	Unsuppl.	Pellet	Unsuppl.	Pellet
4:0	1.17 (0.95) ^c	3.16 (1.78)	1.36 (0.04)	1.46 (0.01)	1.10 (0.02)	1.36 (0.28)
6:0	1.80 (0.12)	3.02 (0.95)	2.01 (0.06)	2.13 (0.08)	1.01 (0.04)	1.11 (0.17)
8:0	2.01 (0.15)	2.34 (0.44)	1.87 (0.02)	1.97 (0.15)	0.76 (0.01)	0.87 (0.90)
10:0	2.66 (0.02)	3.10 (0.32)	2.60 (0.03)	2.75 (0.22)	1.14 (0.01)	1.24 (0.09)
12:0	3.16 (0.15)	3.50 (0.36)	2.99 (0.08)	2.94 (0.15)	1.52 (0.04)	1.59 (0.15)
14:0	12.35 (0.27)	12.66 (0.46)	13.04 (0.12)	12.13 (0.25)	9.98 (0.24)	9.94 (0.59)
14:1	0.67 (0.09)	0.71 (0.02)	0.89 (0.02)	0.91 (0.03)	0.96 (0.07)	0.76 (0.02)
15:0	1.38 (0.03)	1.40 (0.08)	1.70 (0.04)	1.57 (0.01)	1.75 (0.05)	1.56 (0.06)
16:0	26.04 (1.14)	26.54 (0.51)	29.96 (0.31)	30.29 (0.40)	31.44 (0.84)	31.97 (0.15)
16:1	1.98 (0.02)	2.12 (0.22)	1.82 (0.06)	1.85 (0.02)	3.75 (0.02)	3.57 (0.25)
17:0	1.06 (0.07)	1.01 (0.00)	1.10 (0.01)	1.08 (0.01)	1.43 (0.07)	1.24 (0.05)
18:0	15.78 (0.54)	14.54 (0.01)	13.56 (0.28)	13.70 (0.55)	14.68 (0.48)	14.91 (0.40)
18:1	3.44 (0.05)	2.46 (0.48)	3.15 (0.12)	2.61 (0.09)	2.06 (0.04)	1.88 (0.01)
18:2	0.35 (0.03)	0.36 (0.07)	0.36 (0.01)	0.39 (0.02)	0.37 (0.01)	0.41 (0.04)
18:3	1.16 ^d (0.03)	0.86 (0.09)	0.78 ^d (0.08)	0.67 (0.03)	0.90 ^d (0.02)	0.73 (0.08)

^a Number of samples = 2.

^b Number of samples = 4.

^c Number in parentheses is the standard error of the mean.

^d Significant difference ($P < 0.05$) in proportion of fatty acid between unsupplemented and pellet-supplemented groups.

Calf Growth Rates

No significant difference ($P > 0.05$) was detected between the growth rates of calves from the pellet and unsupplemented group hinds, or between calf sexes. There was a significant ($P < 0.001$) and positive relationship between growth rate and age of calf for all calves in the study. The weight of calves, up to 20 weeks of age, can be predicted from age by the following equation:

$$y = 20.23 + 0.75 (x)$$

where: y = Calf weight, kg.

x = Age of Calf in Weeks,

$r^2 = 0.99$,

$n = 120$

Calf Behavior

In this study, no significant difference ($P > 0.05$) was detected in the amount of daylight time spent foraging between calves from pellet or unsupplemented hinds. In addition, there was no significant difference ($P > 0.05$) in the levels of activity or inactivity between the two groups. However, as calves grew older, both groups increased foraging time and decreased time allocated to active behavior. Inactive behavior, in both groups, also decreased as calves grew older.

No significant difference ($P > 0.05$) could be detected in the number of suckling bouts between unsupplemented and pellet calves

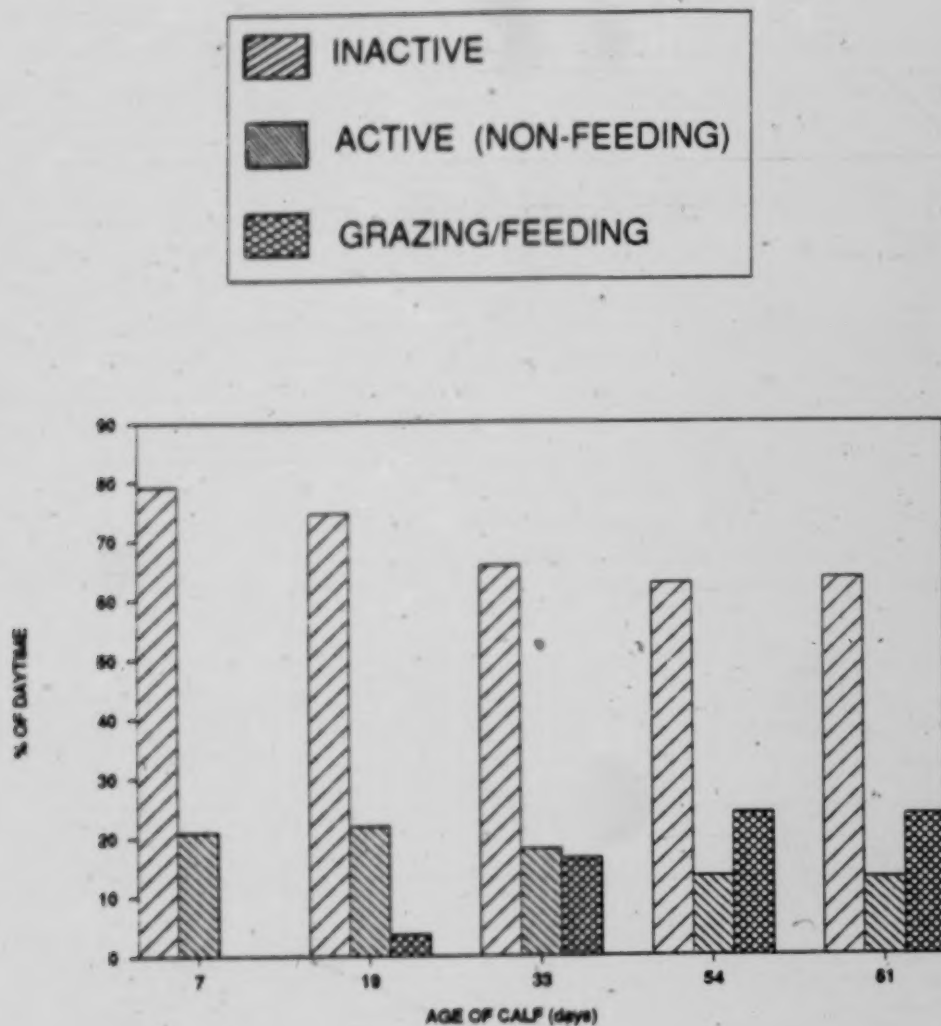


Figure V.5. Combined percent daytime activity of wapiti calves from both winter unsupplemented and pallet-supplemented wapiti hinds at M.W.R.S.

during daylight hours. There was also a trend in both groups to have fewer suckling bouts per day as age of calf increased (Table V.2). No significant difference ($P > 0.05$) could be detected in the length of suckling bouts between calves from unsupplemented or pellet hinds but, there was a trend towards decreasing bout length as calves grew older (Table V.2).

D. Discussion

Milk Production

The milk production values obtained in this study compare favorably to values from other studies with cervids and also reflect the influence of feeding regimes on milk production. The lactation curve of the pellet group compared favorably with the results of Robbins et al. (1981) who found the peak at 21 days in wapiti hinds. The hinds used by Robbins et al. (1981) were fed alfalfa hay ad libitum from early February, to the termination of the study, which was a similar feeding regime to the supplemented hinds in this study. The peak volume of 2962 ml in this study was lower than the peak of 4100 ml reported by Robbins et al. (1981). The average volume of 2180 ml/day over the 150 day lactation period agreed closely with Robbins et al. (1981) average volume of 2700 ml/day. The lower volume of milk at peak lactation observed in this study could be related to the feeding regime during lactation. Loudon et al. (1984) found that pasture quality, during lactation has a significant influence on milk volumes. Red deer hinds on high

Table V.2. Mean $\pm$ SE number of suckling bouts per day and mean duration of suckling bouts for calves from unsupplemented and pellet-supplemented wapiti hinds, combined at M.W.R.S.

Average Age of Calf (days)	Number of Bouts/Day		Bout Length (Minutes)	
	Mean	SE ^a	Mean	SE ^a
19	6	0.60	1.50	0.28
33	8	0.84	1.00	0.07
54	5	0.82	0.96	0.04
61	4	0.52	0.94	0.09

^a Standard error of the mean.

quality pasture produce 60 percent more milk over the lactation period than hinds on poor quality pasture. It is possible that differences in feed quality or quantity during lactation were responsible for lower peak lactation volumes in this study.

The different timing of peak daily volume between the two groups compares favorably with Loudon et al. (1984) who found that peak milk consumption of red deer calves occurs at different times depending on pasture quality. Hinds feeding on high quality pasture underwent peak lactation at 20 days while those on low quality pastures did not reach peak lactation until 40 days. The results from this study suggest that poor nutrition during winter may delay peak milk output in the subsequent lactation.

The results from the suckling technique proved much more variable than hand milking and no treatment differences could be detected. All milk intake estimation methods have potential errors (Oftedal 1984). Suckling methods require that procedures do not alter milk intakes even though suckling durations and intervals may be quite artificial (Oftedal 1985). The importance of using trained animals has been emphasized in domestic animals (Doney et al. 1979) and is even more vital with less docile species (Oftedal 1985). It is possible that the high degree of variation in milk volumes found in early part of this study was due to hinds and/or calves not being habituated to the suckling procedure. The degree of variability lessened later in the study, which may indicate habituation by that time.

Hand milking methods are valid only if: 1) secretion rates are

unaffected by separation and repeated milking; 2) a comparable and relatively complete evacuation of the mammary glands is accomplished at each milking, and; 3) volumes obtained are representative of what the young would consume (Ofstedel 1985). The milk volumes obtained by hand milking in this study would seem to be more representative of actual milk volume because they agree closely with other reported values and are much less variable than the volumes obtained through the weighing technique.

If the conditions associated with either technique cause stress and the endogenous release of adrenaline and noradrenaline, evidence suggests that the milk ejection response may be hindered by: 1) a partial blocking of oxytocin release from the posterior pituitary (Cross 1955); 2) direct inhibition of the action of oxytocin on mammary myoepithelial cells (Chan 1965), or; 3) constriction of mammary blood vessels and increased resistance of the mammary ducts (Hebb and Linzell 1951). In this study a high degree of excitation was noted in hinds during both techniques. The variation in milk volumes obtained through hand milking compared to the suckling technique, used in this study, and the tritium dilution method used Robbins et al. (1981) may be a result of handling stress.

Milk Composition

The concentrations of fat, protein, and lactose in the milk of hinds from both groups, agree closely with those for red deer (Arman et al 1974). Wapiti milk has a high fat and energy content and, as in other deer species, there is an increase in the fat and protein

content with advancing lactation (Arman 1979). The mean values for milk energy over the 150 day lactation for both groups agree with values for red deer (Arman et al. 1974), but are higher than the 5.1 kJ/g reported by Robbins et al. (1981) for wapiti. In the present study, the slightly higher lactose level in the pellet group may be a reflection of the winter nutritional regime. White and Luick (1984) have suggested that low levels of milk lactose may actually reflect the status of body tissue stores of the cows and the primary need for weight gains. A strong feedback mechanism to replenish body condition during the short growing season, prior to the rut, may indeed preempt high lactose production (Renecker 1987). White and Luick (1984) hypothesize that while a need to replenish body stores may be responsible for low lactose concentrations, low lactose may in turn be the mechanism which controls low milk production. Arman (1974) suggests that the secretion of very rich milk would be advantageous to any species subject to predation, provided water is available to the young. Wapiti calves are born with cryptic coloration and exhibit a hiding behavior during the first week of life indicating that they are subject to predation (Johnson, 1951). The adaptive significance of a concentrated milk may be two fold; acting to maximize maternal body condition prior to breeding and, reduction of predation pressure on the young.

The values for fatty acid composition obtained in this study are comparable to those reported by Krzywinski et al. (1980) for captive red deer in Poland. Fatty acids in milk arise from two sources (Eppard et al. 1985). The short and medium chain length fatty acids

as well as half of the palmitic acid (C16:0) in milk fat are synthesized from acetate and β -hydroxybutyrate in the mammary epithelial cells. Mammary uptake of preformed fatty acids (arising from alimentary absorption or the mobilization of body fat) is the source of the remaining palmitate and the long chain fatty acids in milk fat. The differences and changes in milk fat composition in this study are most likely related to energy balance and mobilization of body reserves. The unsupplemented group had a larger proportion of fatty acid C18:3 which may indicate that, to some degree, more body reserves were being mobilized during lactation than in the supplemented group. The higher amounts of long chain and low concentrations of short chain fatty acids in the milk of both groups late in lactation may be a reflection of deteriorating pasture conditions during this period.

Calf Growth and Behavior

Calves from hinds in the pellet group received more energy/day in the milk, but there was no significant difference in growth rates. Mueller (1980) suggested that black-tailed deer fawns with lighter birth weights may consume more milk per unit body weight than do large fawns. Clutton-Brock et al. (1982) found that light-born red deer calves nurse for longer durations than heavy-born calves. It is possible that the heavier calves in this study did not make use of all available milk thus negating any treatment differences.

Robbins and Moen (1975) found that bottle fed white-tailed deer fawns receiving lesser amounts of milk maintain a high rate of gain

by increasing their forage intake. In the present study, no difference was detected in the amount of daylight time spent foraging between calves from pellet or unsupplemented hinds. If grazing and feeding are combined into the active category, the time allocated to these activities are comparable to the results of Podbielancik-Norman et al. (1978) who found that wapiti calves, from birth to 11 weeks of age, are active on average for 27 percent of the daylight hours and that general calf activity increases with age.

Calf activity after dark was not measured in this study. Podbielancik-Norman et al. (1978) estimate that wapiti calves are active on average for 15 percent of the dark hours. It is possible that calves from the unsupplemented hinds, which received less milk energy/day, compensated by grazing and feeding more than the calves from supplemented hinds during the dark hours. This may explain why there was no difference in growth rates between calves from unsupplemented and supplemented hinds.

The observations of suckling behavior in this study agree closely with the results of Podbielancik-Norman et al. (1978) who also found that bout length and duration of suckling bouts decreases with increasing age of the calf. The number of bouts/day at day 19 may be lower than the actual number of bouts due to the lack of night-time observations. The mean duration of suckling bouts agrees closely with results reported by Johnson (1951) for free-ranging wapiti. The results from the present study are in agreement with Robbins et al. (1987) and show that total milk intake, in captive wapiti calves, is determined by a decrease in the frequency of nursing bouts and an

increase in the efficiency of milk extraction and intake per bout.

E. Conclusions

There is no definitive explanation for the similar growth rates of calves from the unsupplemented and pellet group hinds. It is possible that calves from the unsupplemented group, receiving less milk energy, may be spending similar times foraging as treatment calves but choosing forage of better quality. It is also possible that differences not observed during daylight hours may occur during night-time activity bouts. This study does illustrate that previous nutritional history does play a role in subsequent lactation. Although the provision of good quality summer pasture, during lactation, may be the prime factor affecting milk production, good winter nutrition can aid in increasing subsequent milk production.

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VI. SYNTHESIS AND RECOMMENDATIONS

A. Synthesis

Wapiti are well suited to the climatic conditions and forage resources on marginal lands in Alberta (Hudson 1981, Renecker and Kozak 1987). They also express behavioral and metabolic adaptations to a strongly seasonal environment (Hudson et al. 1985). The results from this study reinforce the agricultural potential of wapiti. Animal care standards for allowable winter weight loss and calving assistance have been addressed. In addition, the suitability of different winter feeding systems has been explored.

Wapiti are extremely adaptable in their dietary preference (Gates and Hudson 1981). As a result, supplemental rations can be formulated from a large variety of forages and concentrates that are locally available. Wapiti hinds supplemented with concentrates, such as pellets, have higher intakes but no difference in weight gains when compared to those supplemented with long-hay rations. Wapiti supplemented with a processed concentrate ration spent significantly more daylight hours foraging than their counterparts that were supplemented with long-hay rations. A higher cost is associated with feeding a pellet concentrate due to higher intakes and higher costs of processing the feed. Winter supplementation of wapiti hinds for maintenance is best accomplished with a long-hay diet, although the degree of range utilization can be increased with the provision of concentrates in the diet. Concentrates and forages can be used in

combination to regulate native range use.

On large acreages, with adequate forage resources, wapiti hinds can be pastured throughout the winter. On smaller acreages, natural forage can be complimented with supplemental feed. Calving is not adversely affected when hinds incur weight losses of up to 10% of autumn weight prior to calving, providing the hinds are in good condition entering the winter. Hudson et al. (1985) have demonstrated that small animals lose less weight, in both absolute and relative terms, in spite of the expectation that they would be most disadvantaged by harsh winter conditions. As a result, a 10% weight loss "rule of thumb" would not apply to small hinds in poor condition. In addition, wapiti have the ability to compensate for overwinter weight loss the following spring (Hudson and Watkins 1985).

Conception rates in adult hinds were excellent, exceeding 90%. Only one adult hind failed to conceive over the 2 year period. Age at first conception was variable and conception was more dependent on age than weight. Hinds reaching an autumn target weight of 228 kg conceived, while those weighing less did not. Supplemental feeding of female calves, during their first winter, would enhance the chances of reaching target breeding weights the following autumn.

Wapiti hinds, like domestic species, are subject to dystocia, as a result of fetal malpresentation and fetal oversize. This study suggests that dystocia is more prevalent among heavily supplemented hinds. No differences could be detected in birth weight or vitality

between calves from supplemented or unsupplemented hinds. Calf body size appeared to be the primary determinant of birth weight suggesting little or no differences in fat reserves between calves from supplemented and unsupplemented hinds. Calf birth weight was significantly correlated to age and autumn weight of the hind. Calf vitality was significantly reduced in cases of dystocia especially when assistance had to be provided. The mean length of parturition, from the onset of the second stage of labor, was 30 to 45 minutes for normal parturitions. A hind should be checked to see if assistance is required if no progress is made 1 to 2 hours after the amniotic sac is expelled. In general, the same rules for calving intervention used for domestic cattle can be applied to wapiti (Anon. 1987).

Milk production by wapiti hinds was affected by winter nutritional status. Hinds that experienced overwinter weight loss produced milk slightly higher in fat and protein, but significantly lower volumes. As a result, calves from unsupplemented hinds received significantly lower levels of milk energy per day. Peak milk volumes were also lower and occurred later in lactation in unsupplemented hinds. Significantly higher amounts of the C18:3 long-chain fatty acid found in the milk of unsupplemented hinds indicated that they were mobilizing more body reserves into milk production. unsupplemented hinds showed slightly lower levels of milk lactose than supplemented hinds. A need to replenish body stores may be responsible for low lactose concentrations and, in turn, low lactose may be the mechanism that controls low milk production (White and Luick 1984).

Although calves from unsupplemented hinds received less milk energy per day, no differences in growth rates could be detected between the two groups of calves. It has been found that light-born deer fawns or those receiving less milk may compensate by suckling for longer durations or increasing forage intakes (Clutton-Brock et al. 1982, Robbins and Moen 1975). Daytime calf grazing or suckling behavior did not differ between the two calf groups in this study. Night-time calf activity was not monitored in this study, therefore it is possible that calves from unsupplemented hinds compensated by grazing and feeding more than their counterparts during the night.

The type of supplemental feed may also have an effect on milk production. Three cases of lactation failure occurred in the group of hinds receiving the barley-based pellet ration. Lactation failure and impaired reproductive performance associated with feeding barley-based rations have been reported in other cervids (Arman et al. 1978, R.G. White pers comm 1985, Blanchard and Hauer 1986). Although the exact cause is not known, a disfunction in rumen and/or carbohydrate metabolism is suspected as being the cause (Blanchard and Hauer, 1986). Until more research is carried out in this area, it is recommended that cervid species not be supplemented with barley-based rations. Previous nutritional history does play a role in subsequent milk production. Good quality summer pasture, during lactation, may be the prime factor affecting milk production (Loudon et al. 1974), but good winter nutrition can act to increase subsequent milk production.

B. Recommendations

1. Pregnant wapiti hinds should be allowed to maintain their weight, or lose up to 10% of autumn weight during the winter in order to ensure successful calving.
2. Supplementation of pregnant wapiti hinds through the winter, for maintenance and successful reproduction, is best accomplished with a ration of good quality grass/alfalfa hay.
3. The provision of concentrate rations to wapiti hinds is recommended to reinforce behavior or used in combination with forages to increase the level of native range utilization.
4. Winter feed costs can be minimized by the provision of a long-hay (grass/alfalfa) ration to pregnant wapiti hinds during winter.
5. Heavy supplementation of pregnant wapiti hinds, especially during the last four weeks prior to parturition, should be avoided as it may contribute to dystocia.
6. A hind should be checked for possible dystocia problems if no progress in calving is made 1 to 2 hours after the onset of the second stage of parturition.

7. Supplementation of wapiti hinds with barley-based rations should be avoided as it may lead to cases of dystocia and/or lactation failure.
8. Female wapiti calves should be supplemented ad libitum during their first winter in order to enhance chances of reaching target breeding weights the following autumn.
9. Good winter nutrition should be provided to pregnant wapiti hinds because it can aid in subsequent milk production.

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